

The Geology and Coal Resources of the Coal-Bearing Portions of Wise and Scott Counties, Virginia

A dissertation presented to the Board of University Studies
of Johns Hopkins University for the degree of
Doctor of Philosophy

By
JAMES BRIAN EBY
BALTIMORE
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PREFACE

The writer of this paper has spent the major portion of two field seasons examining the coal fields of Wise and Scott counties, Virginia. The expense of the work was borne jointly by the United States Geological Survey and the Virginia Geological Survey and the contents of this paper, with additional matter not here given, will be published later as a bulletin of the Virginia Geological Survey. The field is the most prolific producer of coal in the State of Virginia and as the production from Scott County is negligible the field is commonly called the "Wise County coal field." The annual production from this field alone is greater than the annual production from all the remaining fields in the State of Virginia combined.

The present paper is the first attempt to make a detailed study of the field as a whole. Many important "intra"-county correlations of coal beds had to be made in tying together the areas within the field that had been mapped individually and at different times. No efforts have been spared to obtain all possible detail pertaining to the geology of the coal-bearing rocks and the occurrence, availability, and quality of the coal. The orderly presentation of the great mass of data obtained in this field is accomplished by dividing the field into its natural drainage basins and discussing the coal beds outcropping therein. Following the detailed description of the coal beds the quality and chemical character of the various coals is reviewed and a number of chemical analyses of coals in the field are given.

The geology of the field is typical of the Appalachian type of folding. The major faults and folds of the region follow the general northeast-southwest trend of the Appalachians and the attitude of the rocks clearly indicates that the direction from which the fold- and fault-producing forces were applied was from the southwest. The coal basins in general lie in a broad shallow syncline that has been formed by the faulting up of the rocks on the two sides of its axis. The structure within this synclinal basin, however, is not simple, being considerably modified by minor transverse folds. The mapping and structure contouring of these minor folds presented many of the most difficult problems met with in the field. To the solution of many of these structural problems the writer here wishes to express his gratitude for the invaluable assistance and suggestions of Mr. M. R. Campbell and Mr. George W. Stose, of the United States Geological Survey, and of Professor Harry Fielding Reid, of the Geological Department of the Johns Hopkins University.

THE GEOLOGY AND COAL RESOURCES OF THE COAL-BEARING PORTIONS OF WISE AND SCOTT COUNTIES, VIRGINIA

INTRODUCTION

Location and importance of the field.—The region treated in this report lies in southwest Virginia (Fig. 1), and includes Wise County which is bounded on the northeast by Dickenson County, on the northwest by Pike, Letcher and Harlan counties, Kentucky, on the southwest by Lee County, on the south by Scott County, and on the east by Russell County and a small strip of Scott County, adjacent to Wise, which in a general way is bounded on the south by the Hunter Valley road and on the west by the Southern Railway. It includes 451 square miles of coal land on the southeast border of the great Appalachian coal region, and approximately 45 square miles of non-coal land.

The wealth of mineral resources in Wise far surpasses that of any other county in Virginia. Records¹ show that the coal produced in this county in 1917 and 1918 exceeded by thousands of tons the entire amount of coal mined in the remainder of the State; the coal mined in Scott County in the same years was negligibly small, there being only 3 or 4 operating mines. It is estimated that 5,778,280,000 tons of high grade bituminous coal in beds over 14 inches thick still remain in Wise and Scott counties. Railroads, entering Wise county from the northeast, southeast and southwest, have opened for development much of the best coal land of that county, but thousands of acres containing mineral coal have not yet been reached. This is true especially of the coal in the Pound River drainage basin. The great potential value of this coal is not equaled in any of the other coal-bearing counties of Virginia. In this regard Scott County is much less fortunate, its beds being thinner, less easily accessible, and of considerably smaller areal extent.

Iron ore occurs in Wise County in sufficient abundance and purity to make it a factor in the mineral wealth of the county. It has been mined and smelted near Big Stone Gap, Va., for nearly thirty years. Flux for the ore is also found in quantity in the limestone strata that outcrop for

¹ Leshner, C. E., Coal in 1918: U. S. Geol. Survey Mineral Resources, 1918, p. 803, 1920.



Fig. 1.—Index map showing the location of Wise County and the coal-bearing portion of Scott County, Virginia (shaded area).

many miles in the vicinity of the town. No iron ore of commercial importance is found in the coal-bearing portion of either Wise or Scott counties.

Lumbering ranks among the major industries. Large mills are operating in various parts of Wise and Scott counties, as on Dry Creek, near Dungannon, on Stony Creek above Ka, and on Pigeon Creek, near Exeter. Hundreds of small sawmills are scattered about the wooded slopes of the two counties.

Thousands of acres of farm land have been obtained by clearing the forest from the plateaus, valley bottoms and gentle slopes. This is par-

ticularly true of the broad plateau in the vicinity of Wise on which many farms are located and on the rounded swell of Powell Mountain south of Coeburn, the latter region being known locally as the "Flatwoods." The wide valley of the South Fork of Powell River and Butcher Creek is also excellent farming land. The hilly character of the northern part of Wise County restricts farming in that region mainly to the narrow valleys and clearings on steep slopes. Corn, wheat, oats, and alfalfa, are among the staple crops produced. Apples constitute the chief fruit, and are grown in abundance.

Cattle and hogs are raised in large numbers. The more gentle slopes and ridge tops afford pasture land that exceeds 100,000 acres in extent. Horses, sheep and poultry are also raised throughout the region.

Prior to the early nineties the region was sparsely settled. The inhabitants then were for the most part descendants of the earliest settlers. The great increase of population began with the coming of the railroads, and the opening of coal mines and the newcomers gathered in towns on the railroads and around the coal mines.

The population of Wise County in 1920 was 46,500,¹ consisting mainly of whites, but including several settlements of negroes in the mining districts. The white population is predominantly native American but there are many settlements of foreigners near several of the larger coal mines. The foreign element consists in the main of English, German, Hungarian and southern European stock. One-ninth of the entire population is employed in the coal mining industry and an equal number is dependent on allied industries for support. Of the remaining seven-ninths of the population the great majority are engaged in farming, fruit growing, and stock raising and are native southwest Virginians.

Norton, with a population of 3,068, is the largest town in Wise County. It is the terminus of the Clinch Valley division of the Norfolk and Western Railway, and of the Cumberland Valley division of the Louisville and Nashville Railway. Other towns of importance in the county have the following population: Big Stone Gap, 3,009; Appalachia, 2,036; Wise, the county seat, 1,071; Coeburn, 884; and St. Paul 574. No towns are located in the part of Scott county covered by this report.

Political history.—The region of southwest Virginia now included in Wise and Scott counties was the home of Indian tribes long before the advent of the white man on this continent. The earliest Indian inhabitants

¹ All figures indicating population are from the census of 1920.

of which there is record were Xualans.¹ This tribe was driven out of the territory some time between 1671 and 1685 by the Cherokee Indians, and the latter were themselves soon expelled by the conquests of the Confederacy of Six Nations. For the following hundred years the county was an unsettled wilderness, entered only occasionally by nomadic bands of natives.

Exploration in southwest Virginia by white adventurers began as early as the middle of the seventeenth century. New River was first discovered and named, it is said,² by Colonel Abraham Wood, in 1654, who lived near the falls of the Appomattox, the present site of Petersburg. The name Woods River was given it by the discoverer, though the term New River was used at the same time and interchangeably by the explorers, expressing the fact that to the white men the stream was truly a "new" river. Exploration and settlement of southwest Virginia was encouraged by the civil and military leaders of the State, Governor Alexander Spotswood being one of the pioneer explorers. He reached the summit of one of the high peaks of the Blue Ridge at Swift Run Gap, Augusta County, Virginia, in September, 1716.

The territory now included in Wise County was very sparsely settled prior to the Revolution; Fort Blackmore had been established and another blockhouse had been built at Castlewood near St. Paul in 1775. Indian depredations discouraged the ready settlement of the region. Daniel Boone and Christopher Gist were probably the most famous early explorers to traverse the wilderness on Powell and Guest rivers.

All of that part of Virginia lying west of the Blue Ridge Mountains was originally embraced in Orange County. In 1738 it was divided into Frederick and Augusta counties, though it was not until 1745 that the latter county was organized. The present county of Wise was a portion of Augusta County. Southwest Virginia was further subdivided by an act of the House of Burgess of Virginia in 1769, in forming Botetourt County, which was to contain all the territory of Augusta County lying south and west of North River, near Lexington. The first court was held on February 13, 1770, near Fincastle. The territory drained by waters of the Mississippi was separated from Augusta County in 1773 and organized under the name Fincastle, with its seat at the lead mines on New River, now in Wythe County.

¹ Summers, L. P., *History of Southwest Virginia*—Richmond, 1903, p. 23.

² Hale, John P., *Trans-Allegheny Pioneers*, Cincinnati, 1886, p. 21.

All of that territory now called southwest Virginia was included in Washington County, as established by the General Assembly of Virginia on December 6, 1776. Court was first held at Blacks Fort, now Abingdon, which is now the seat of Washington County. After the Revolutionary War the increase of population demanded the formation of still more counties and Russell, Scott, and Lee were formed. Wise county was organized on February 16, 1856, and held its first court on July 28, of that year. The county was named for General Henry A. Wise who was Governor of Virginia from 1856 to 1860. Except for the loss, on February 27, 1880, of a magisterial district in the formation of Dickenson County, the boundaries have remained essentially the same to the present time.

The first presiding justice for Wise County was William Richmond who held his first court in a small Baptist Church about 200 yards southwest of the present courthouse at Wise. The first Grand Jury met in the open, near the church.¹ The commonwealth attorney was William B. Aston, the county clerk was Morgan T. Lipps, and the sheriff Andrew J. Dotson. The town at that time was called Gladeville and had a population of about two hundred and fifty.

The log courthouse built in the latter part of 1856 was burned by the Union forces during the Civil War. Many records of the county were lost, but those of the proceedings of the court which had been hidden were saved. The present courthouse was begun in 1896, replacing a smaller brick building that had been put up immediately after the war. Wise, or Gladeville, as it was then known, remained the chief town until after the coming of the railroads when larger centers of industry and population arose. In 1890 the number of inhabitants of Wise County was 9,346, in 1900, 19,653, and in 1910, 34,162.

Many of the names of settlements and of topographic features come from pioneer days. Powell River received its name from Ambrose Powell, one of a party of explorers that crossed the stream near Cumberland Gap in 1750.² Guest River takes its name from Gist, the explorer, and Toms Creek from his son, Thomas. It is interesting to note that the last recorded incursion of the Indians into southwest Virginia ended in their defeat on Stone Mountain, south of Dorchester. Bengé, the half breed leader of the band had captured a Mrs. Livingston from near the present town of Mendota

¹ The sessions were held on the large flat-topped sandstone which is still commonly known as "Grand Jury Rock."

² Summers, L. P., *History Southwest Virginia*—Richmond, 1903, p. 50.

in Washington County, on April 6, 1794, and was returning westward when overtaken and killed. Benges Gap and Benges Branch take their names from this Indian Leader. Giving streams and ridges names that suggest particular physical conditions was a common practice. Thus there are several Laurel forks, Dry creeks, Glady branches, Big and Little creeks, Straight forks and Clear creeks. Gladeville was named from the "Big Glades" which occur on the top of the thick white sandstone that forms the surface of the plateau. Norton was called Prince's Flat, prior to 1890, but received its present name from stockholders in the company which owned the property upon which the town was laid out after the coming of the railroads. Coeburn was named for W. W. Coe, an official of the Norfolk and Western Railroad, who surveyed the town in 1888 and Judge William E. Burns, a stockholder in the new corporation. With the coming of large outside coal corporations, names quite foreign to southwest Virginia have been brought in for scores of the newest towns.

Development of the coal mining industry.—The presence of coal in southwest Virginia was noted by white explorers long before the Revolutionary War. Thomas Jefferson in his notes on the State of Virginia, written as early as 1782, mentions its occurrence as follows:¹

"In the western country coal is known to be in so many places as to have induced an opinion that the whole tract between the Laurel Mountain, Mississippi, and Ohio yields coal"

Laurel Mountain as indicated by the writer on his map of the State represents the present Cumberland Mountain. The State boundaries as drawn place the Wise County of today well into Lincoln County, Kentucky, of that day, the Virginia-Kentucky line running due north from just east of the junction of North and Middle Forks of Holston River.

The value of coal as a great natural resource was not considered in the early days. That it was used locally to considerable extent, however, is certain, and by 1835 coal in the Kanawha basin was being used in the manufacturing of salt. Rogers,² the eminent Virginia geologist, writing in 1835 said:

"The importance and value of salines in this vicinity [Charleston] may be inferred from the fact that about three million bushels of salt are now made annually from them and that in the manufacture of this

¹ Jefferson, Thomas, Notes on Virginia: London, 1787, p. 42.

² Rogers, W. B., The Geology of the Virginias, New York, 1884, p. 118.

article alone more than twice the quantity of coal is consumed every year than is furnished by all the coal mines of eastern Virginia put together. This coal being procured from the hills adjacent to the salt furnaces is obtained at comparatively little cost; presenting an example of the fortunate adaptation of resources to each other."

Practically no coal was mined in Wise County for other than purely local use prior to the Civil War. Among the first mines to be opened were those on Toms Creek and Crab Orchard Creek. In a paper on the geology of the region, J. P. Leslie¹ reported prospect pits in a 5 to 6 foot bed at Guest's Station (junction of Big and Little Toms creeks) and on Crab Orchard Creek "in a fine six foot bed of rather handsome flaming coal, solid enough to wagon over rough roads and not making much ashes or clinker in the grates."²

Prof. Leslie was examining the region for the purpose of determining the nearest possible approach to a workable coal region of a railway planned to run from Harpers Ferry to Knoxville, Tennessee. He reached the conclusion³ that the Guest River Gorge was the natural gateway for a railway line to the Wise County and Kentucky coal fields. It is interesting to note that Professor Leslie was probably the first to realize the coking possibilities of Wise County coals, reporting that⁴ "It is good blacksmith coal [at Guest Station] and no doubt will make good coke. A piece of ill-made coke from what is perhaps the same bed, near Gladeville [Wise], shows that the best coke can be got from it." The coals farther east, in Russell County, the same authority asserts, were extensively mined by the Confederates during the war.

Major Hotchkiss, a mining engineer reporting on the coal fields of southwest Virginia in 1876 did much to focus attention on the coals of Wise and Scott counties. In his report to the Virginia Board of Immigration he states in part,⁵

"Nowhere else in the Union do we find the same condition of things as that existing here, 'where the limestones of the Lower

¹ Leslie, J. P., Amer. Phil. Soc. Proc.: vol. XII, p. 489, 1872.

² Op. cit., p. 492.

³ Op. cit., p. 492.

⁴ Op. cit., p. 494.

⁵ Hotchkiss, Jed., Virginia—Richmond: p. 45, 1876.

Silurian, holding the brown hematite ores, directly abut against the coal beds of the carboniferous and sub-carboniferous¹ era'—the result of great upheavals and downthrows that have brought . . . the most valuable ores of iron alongside the coals without an intervening mountain barrier. The line of fissure, where these formations meet, is in the valley of the Clinch River so that the branches of the stream from the west flow from the coal measures 'for about 70 miles along the valley of the Clinch, any railroad descending the Clinch from Jeffersonville to the mouth of Guest River in Wise County may have as many collieries alongside of it as it pleases.'"

In spite of these reports little effort was made to exploit the numerous resources of the county before 1880. The history of the coal-mining development of Wise County from the year 1880 is briefly and concisely stated by General Ayers of Big Stone Gap, as follows:²

"At a club dinner in Pittsburg in December, 1879, General John D. Imboden, of Virginia, then residing in that city, was called upon for a speech, and responding talked of the rich undeveloped iron ores and coals of Southwest Virginia, and so impressed his audience that a number of business men present at once made up a purse and sent General Imboden out to make an examination and report. General Imboden came out to Bristol, Virginia-Tennessee, the then nearest railroad point, and rode out on horseback and looked over the iron ore and coal fields of Wise and Lee counties and made his report, having taken options upon three large coal properties then for sale. The result was that a purchase was made of the Olinger survey, embracing forty-two thousand acres (42,000) by C. S. O. Tintsman, of Pittsburg, and associates.

"Some time after this E. K. Hyndman, then Superintendent of the Western Division of the Baltimore and Ohio Railroad became interested in the properties, and another large boundary, containing twenty-five thousand (25,000) acres was purchased by him from Patrick Hagan and in March, 1881, Hyndman purchased the interests of his associates and became the owner of the whole.

"Hyndman was then engaged in driving shafts and developing the now celebrated Connellsville coal for the Connellsville Coal and Iron Company, composed of leading men of Mauch Chunk and Philadelphia, Pennsylvania, John Leisenring, John C. Bullitt, Samuel Dickson, Robert H. Sayre, Samuel Thomas, J. S. Wentz, M. S. Kemmerer and others. Hyndman soon interested these people in his Virginia properties and one year later The Virginia Coal and Iron

¹ Leslie, J. P., Amer. Phil. Soc. Proc.: vol. XII, p. 498, 1872.

² Ayers, Rufus A., History of Wise County: Crawford's Weekly, Norton, Va., October, 1920.

Company [1882] was chartered by the General Assembly of Virginia, and upon its organization took over Hyndman's Virginia lands. This was the first large purchase of coal lands in Wise County by coal men for development, and was the commencement of a movement which afterwards led to the purchase of nearly all the coal lands in Wise County by practical coal men and greatly improved the prospects and enhanced the value of its real property.

"The development of these properties was however delayed for many years for lack of transportation, and it was not until 1890 and 1891 that Wise County secured railroads. When they did come they came with a rush. The South Atlantic and Ohio Railroad (now the Southern) was completed in the spring of 1890 and the Louisville and Nashville and Norfolk and Western Railroads were completed to a junction at Norton in 1891, and the development of the coal and iron of the county commenced; few mines were opened however until 1895 and singular to say, the first iron made at Big Stone Gap was made with Pocahontas coke, although there was unequalled coking coal within a rifle shot of the plant. However from 1895, the development grew rapidly, coke ovens were built, mines opened, branch railroads built, mining towns built, other enterprises established; the population largely increased and fine school buildings and churches erected."

The first coal mined and shipped from Wise County was taken from drifts on Looney Creek in 1892, by the Virginia, Tennessee and Carolina Steel and Iron Company. The coal was shipped out over the South Atlantic and Ohio Railway (now the Southern Railway). Other mines were opened the same year at Norton and at Banner. Robert Fleming, of Norton, one of the first to develop the Banner and Norton fields, states that the No. 1 Norton bed was the first utilized and that Norton mines No. 1, No. 4 and No. 7 were opened in 1892. The operation at Banner was in the Kennedy bed and was in charge of the Virginia Gas Coal Company.

Coke was first made at Norton by Mr. Fleming. By heating coal in a two inch pipe partially stoppered at both ends he obtained a rather poor coke. Several car loads of coal were sent to Pocahontas and coked and the results were declared successful, putting an end to the prevailing impression that the Norton coals would not coke.

The Stonega Coke and Coal Company completed their first hundred ovens in the spring of 1896. This company is now the largest coal and coke producer in the county. The Tennessee Coal and Iron Company built ovens in 1897 and 1898 on Toms Creek. Following these, other operations were begun as rapidly as railroad facilities permitted.

It is interesting to note that foreign capital was conspicuous in the development of the region. English capitalists, with Swiss and Dutch were

first to enter the field. Boissevain, a European banker of Switzerland, represented both Dutch and Swiss interests in the field. Robert Fleming¹ of Scotland also invested large sums for the exploitation of the Wise coal field. At present, however, no foreign interests are connected with mining operations in Wise or Scott counties.

Method of geological work.—The present geologic and topographic survey of Wise County and the coal-bearing portion of Scott County was carried on jointly by the United States Geological Survey and the Virginia Geological Survey. The expense of the work was shared by the two organizations.

The topographic map for this report was begun in 1911, with the survey of the Pound River and Birchfield Creek drainage basins. The Guest River basins were surveyed during the field seasons of 1916 to 1921. The geological examination of the Pound River basin was made simultaneously with the work of the topographic corps. On the drainage basins of the other major streams the geologists had the advantage of working on the finished topographic maps.

The method of geologic work was adapted to the hilly, wooded type of country so characteristic of Wise and northern Scott counties. Geologic profiles were made of roads, stream courses and ridge lines. The profile shows the vertical section of sandstones, shales, and coals, as noted by the observer along any given path, elevations being constantly read from the barometer and the profile sketched to a vertical scale in a notebook. Reference to all locations was made on the field map and in the notebook profile by letters or numbers. Where exposures permitted, measurements were made of the various strata and are given in the table of local sections, pp. 87 to 114.

The presence of distinctive coal beds and massive sandstones has greatly facilitated the work of determining the structure and the succession of formations. Thus in the Coeburn region the Upper Banner coal bed is recognizable throughout a large area by a very persistent sandstone parting, and in the Stonega field a layer of coal within the Imboden bed, showing wavy or curved fracture surfaces, and called by the miners "curly" coal, is characteristic of the bed. The sandstone bed at Wise is so massive and persistent a feature that it was named the Gladeville sandstone by Campbell,²

¹Not related to Robert Fleming of Norton, Virginia.

²Campbell, M. R., *Geology of the Big Stone Gap Coal Field of Virginia and Kentucky*, U. S. Geol. Bull. 111, p. 33, 1893.

and mapped by him as a formation unit throughout the entire county and into the adjacent counties. In other parts of the vertical section, sandstone strata have in many places served as key rocks.

In determining the geologic structure of the coal field of Wise County, the geologists have been greatly aided by the extensive developments of the coal companies, both in their underground operations and their core drilling and prospecting. Outcrops have been traced by company engineers throughout a large portion of the field, and accurate elevations of the coal beds determined. Information of this character was cheerfully furnished by all the companies in-so-far as they were able. Outside of the area of active mining the elevation of old coal mines and prospects was determined by aneroid barometer, which was checked during the day as many times as possible by bench marks or stadia stations, thus minimizing the error due to changing atmospheric pressure. All coal prospects and blooms seen by or reported to the geologists were visited and measurements made of the coal exposed. Samples of coal were collected for chemical analysis and ash fusion tests from nearly all the important mines in Wise and Scott counties. Several samples were collected from prospect pits and wagon mines in an effort to give as wide range as possible to the stratigraphic and geographic distribution of the samples taken. The strike and dip of the beds were determined as accurately as the exposures would permit. All coal locations were plotted on a base map, including symbols showing the strike and dip of the coal beds.

The final geologic map of Wise and northern Scott counties was made in the office at the completion of the field season. In its compilation all the data of field notes, maps, trustworthy outcrop surveys, borehole sections and kindred records have been thoroughly digested and used.

Acknowledgments.—Much valuable information was placed at the disposal of the writer by officials and employees of the many coal corporations and companies in the Wise County field. W. D. Tyler, of the Clinchfield Coal Corporation, furnished maps of transit surveys of coal outcrops in the basins of Birchfield, Bowlecamp and Indian Creeks, and the South Fork of Pound and Upper Guest rivers. The surveys included hundreds of measured sections of coal beds, many of which are given in the following text. The Clinchfield Coal Corporation through Mr. Tyler has also permitted with qualifications, the use of the records of the many drill holes put down in or near Wise County. D. D. Hull, Jr., vice-president of the Virginia Iron, Coal and Coke Co., through D. A. Patterson, general superintendent

of mines at Toms Creek, furnished surveys of coal outcrops, drill-hole records and coal sections, for much of the Toms Creek, Bull Run, Russell Creek and Looney Creek basins. J. A. Deaton, chief engineer of the company, coöperated generously in supplying the engineering and coal data.

In western Wise County the Virginia Iron, Coal and Coke Co., and the Stonega Coke and Coal Co., supplied considerable important data. E. J. Prescott, vice-president of the former company, gave bore-hole records and coal outcrop surveys of the Callahan and Roaring Fork basins. Otis Mouser, vice-president of the latter company permitted the use of the records of his company. The writer is greatly indebted to J. B. Rogers, chief engineer of the Stonega Coke and Coal Co., for his helpful coöperation in furnishing data on coal surveys, bore-holes, etc.; for many valuable suggestions; and for the use of the engineering facilities of the company. A. R. Gordon and C. Bailey, of the engineering department, spent considerable time and effort in placing a great amount of data within reach of the writer. The data furnished by this company cover the Pigeon Creek and Callahan Creek basins. The Stonega Coke and Coal Co., has also given many excellent photographs illustrating different phases of mining in Wise County for publication in this report.

In central Wise County the Wise Coal and Coke Co., the Norton Coal Co., and the Blackwood Coal and Coke Co., have furnished considerable information on the coal beds of that section of the field. D. Terpstra, general manager of the Wise Coal and Coke Co., extended the use of all the records of his engineering office and every facility for the furtherance of the field work. The many bore-hole records of the company are most valuable. The Norton Coal Co., through J. K. Taggart, general manager, gave coal sections and bore-hole records of the lower portion of the Upper Guest River basin. C. J. Creveling, general manager of the Blackwood Coal and Coke Co., furnished much information on the coal beds of Black Creek and Roaring Fork, and E. L. Gobble, chief engineer, spent considerable time with the writer in supplying and arranging the data. G. C. Scarborough and F. T. Dotson, civil and mining engineers, of Norton, and D. E. Llewellyn, consulting engineer, of Wise, assisted greatly by furnishing coal outcrop maps, coal sections and general information on the Upper Guest River and Bear Creek basins.

Information of value to the report was also furnished by R. A. Ayers, R. T. Irvine, E. B. Lipps, G. V. Hughes, Malcolm Smith and others of

Wise County and by C. A. Bilips of the United States Coal and Coke Co., Lynch, Kentucky. The writer is also indebted to J. L. Wells for transit work done for this report.

Free use has been made of all previous publications in the preparation of this report. The field was mapped in large part by M. R. Campbell for the Bristol and Estillville folios of the United States Geological Survey. The field was described in 1893 from the economic standpoint by Campbell in Bulletin 111 of the U. S. Geological Survey. Campbell and Woodruff described a small part of the Powell Mountain coal field in Bulletin 431 of the United States Geological Survey, 1909. Charles Butts reported on the Geology of the Pound Quadrangle, Virginia, in Bulletin IX of the Virginia Survey and in Bulletin 541 of the U. S. Geological Survey.

The writer is greatly indebted to Mr. Campbell of the United States Geological Survey, who had general supervision of the present work, for his critical field examination in the fall of 1920 and in the spring of 1921, and his invaluable suggestions and coöperation in the office preparation of the report. As the result of his work on Black Creek, Powell River, and Upper Guest River, many of the outstanding problems in coal correlation were solved. Parts of the field were mapped by C. K. Wentworth of the United States Geological Survey and A. W. Giles of the Virginia Geological Survey. Mr. Wentworth spent part of the summer and fall of 1919 and the entire spring and summer of 1920 in Wise County mapping the Powell Mountain district, and parts of the Coeburn district. He also made many traverses in western and central Wise County. The writer received many helpful suggestions from Mr. Wentworth. Parts of the Toms Creek basin and eastern Powell Mountain were mapped by Mr. Giles in the summer of 1919.

David White, of the United States Geological Survey, spent several days in the field collecting plant fossils and later devoted considerable time in the office to studying the collection for the purpose of making correlations within the field and also with other fields of the Appalachian region. He also made a special visit to the field in company with the writer in the autumn of 1922 to determine the age of the Burtons Ford coal bed.

The writer wishes to express his indebtedness to Doctor Thomas L. Watson, director of the Virginia Geological Survey, for his unqualified permission to use the geologic and economic report of Wise County, Virginia, for presentation to the Board of University Studies of the Johns Hopkins University as a dissertation. Much of the material contained

in the following manuscript is taken from the report on Wise County prepared by the writer for publication as a Virginia Survey Bulletin. During the course of the field and office work the writer was a member of the United States Geological Survey, which coöperated with the State Survey in the preparation of the report.

The writer expresses here his sincere appreciation and gratitude for the timely attention and material assistance received from the faculty of the Geological Department of the Johns Hopkins University. Prof. Edward B. Mathews has given the writer much valuable assistance, Prof. Harry Fielding Reid, Prof. Edward W. Berry, Prof. C. K. Swartz, and Prof. J. T. Singewald, Jr., have also given freely of their time and counsel to the discussion and solution of the field and office work, for which the writer is deeply indebted.

GEOGRAPHY

Surface Features.

General characteristics of the field.—The Wise and Scott County fields are included in what physiographers call the Appalachian Plateaus that consist of several plateaus which in some places have flat tops but in other places have been so dissected by the streams that only hills and ridges remain. These plateaus lie to the northwest of the long straight ridge of Stone Mountain from south of Cumberland Gap to Little Stone Gap in Wise County. Here the boundary swings to the south and west and encloses the plateau of Powell Mountain which forms a projecting salient in the generally straight boundary of the coal field. From the southern point of Powell Mountain the boundary of the coal field and the Allegheny plateaus is a straight northeast line to beyond the margin of the territory here described and mapped.

Southeast of the line forming the southeastern boundary of the coal field lies the Appalachian Valley province which in general consists of rudely parallel valleys and ridges, the valleys general being eroded in limestone or soft shale and the ridges being formed of the more resistant sandstone. The only part of this province that falls within the area shown on the map is Powell Valley in the vicinity of the town of Big Stone Gap. This will be described more fully on another page.

In general the Appalachian Plateaus consist of an upland which is highest on the east and slopes gradually westward until it reaches nearly the

level of the lowland or ordinary surface in central Kentucky and Ohio. In most places the streams have cut so deeply into this upland that its plateau-like character has disappeared and the surface consists only of hills and irregular ridges rising to a fairly common level. In places the upland surface has been protected from the cutting of the streams by hard beds of flat-lying rocks and here the plateau is quite well preserved. This is particularly true of the Cumberland Plateau of Tennessee and the Allegheny Plateau of Pennsylvania. In other places mountains stood upon the surface of the upland before it was attacked by the streams and today these same mountains, though much reduced and dissected by the streams, still stand above the hill tops of the surrounding region. The mountainous part includes the Black Mountains on the border of Wise County, Pine and Cumberland mountains, and a high, irregular group of mountains in Tennessee.

Wise County is situated on the border line between the mountainous region to the southwest and the deeply dissected, but even-topped upland on the northeast and partakes of the character of both.

In some places the plateaus of this province extend unbroken to its extreme southeastern border, but in others the border is marked by a linear ridge or mountain formed of upturned rocks. Thus the border from Cumberland Gap northeastward is marked by the sharp regular crests of Cumberland and Stone mountains as far as Little Stone Gap south of Norton and on the southeast side of Powell Mountain by a similar, though not so high a ridge from the southwestern point of Powell Mountain to beyond the limits of Scott and Wise counties. Farther northeast the ridge at the southeastern margin of the field is less conspicuous, because the rocks in the lower part of the coal-bearing formation are less resistant to erosion and they have been cut down to the general level of the hilltops in the surrounding region.

Detailed characteristics of the field.—The coal fields of Wise and Scott counties contain almost all types of surface forms that are found in the Appalachian Plateaus. In most places the surface consists of an originally slightly sloping plateau which has been so completely dissected by the streams that little or no remnants of the old plain remain on the hilltops, but the dissection has not been carried on to such an extent as to produce valleys of any great width. As a consequence of this deep erosion by the streams the surface generally consists of sharply cut V-shaped valleys separated by equally sharp ridges and the slopes leading from one to the other are almost as steep as the rocks will stand.

A country composed almost wholly of steep slopes is not well adapted to agricultural pursuits for the ridge tops are generally too narrow to be farmed, the slopes are too steep, and even the valleys will permit only of small farms on the benches and limited flood plains of the rivers. For coal-mining, however, the deep dissection is very favorable as most of the coal beds crop out on the hill sides and only a slight cover of waste material needs to be removed to expose them in their full thickness. The deep valleys also permit of the opening of mines in most of the beds by simply drifting into the hill side at tippie height, or if the coal bed lies too high on the hillside by an inclined tramroad. The building and operation of railroad lines is somewhat difficult and expensive in such a country, and railroads are confined almost entirely to the valleys, but as these ramify into all parts of the field a railroad up a master stream with branches up side valleys makes almost all of the drainage basin accessible.

In places, as on Sandy Ridge and about Wise in the eastern part of Wise County and on some parts of the broad arch of Powell Mountain in Wise and Scott counties, particularly resistant beds of sandstone or conglomerate have so retarded the action of the stream that the old plateau-like surface has been retained in much the same condition that it was when this plain was developed in ages long past and today these features stand out as distinct plateaus and as good examples of what almost all of the surface of this county was like before it was cut to pieces by the streams. Most of the farming land of the coal field is found on these plateaus.

The surface forms whose tops stood above the plain that once characterized the greater part of the coal region are the Black Mountains, on the northwest, Pine Mountain on the north, and Stone, Little Stone and Powell mountains on the south. All of these except Black Mountain and Powell Mountain are linear ridges whose form is controlled largely by the upturned resistant beds that form them. Such mountains as a rule are more regular and persistent than mountains composed of horizontal rocks and hence are more formidable barriers to transportation and mining. Pine and Black Mountains form a great natural barrier between Kentucky and Virginia, with Pound Gap the only wagon route in this area over the former mountain. The northwest slope of Pine Mountain is an escarpment 1,500 to 2,000 feet high, which presents a striking front, as its crest is scarcely a mile from the valley floors of Elkhorn Creek and the North Fork of Kentucky River. No water gap pierces this divide in Wise County, the nearest one being the "Breaks of Sandy", the profound gorge of Russell Fork, in Dickenson

County, 20 miles to the northeast. The southeast slope of Pine Mountain is practically a dip slope on massive sandstone beds and the streams flow off in straight structurally-determined courses into Pound River and its North Fork.

The region drained by Pound River and its tributaries is a country of narrow circuitous divides, and peaked hills, with steep slopes. Flat Gap is a low pass in the divide between the waters of Pound and Cumberland rivers. Within a radius of three and one-half miles of this gap, it is interesting to note that the waters of five different major drainage systems may be reached through the headwaters of Cumberland, Kentucky, Pound, Powell and Guest rivers.

The rough, broken surface of west-central Wise County is somewhat similar to that of the northern territory. Few people live on Pigeon Creek and Bearpen Branch outside of the coal-mining settlements of Exeter and Imboden, as farming is very difficult and in many places impractical. Farther east on Callahan Creek and Roaring Fork the valleys are wider, the hills lower, and their sides less steep. This ease of approach has led to the construction of railroads up the valleys of these creeks and has thus paved the way for the present development of the coal beds. From Roaring Fork east to Norton the ridges are held up by a thick sandstone near their summits which gives this region many of the plateau features.

Strikingly different surface forms are found on Powell Mountain. Wild and almost inaccessible canyons have been cut by the streams in sandstone and conglomerate beds of extraordinary thickness. The impressive walls of these canyons, in many places, rise vertically from 100 to 300 feet, presenting the most serious obstacle to the building of transportation lines into the field. The South Fork of Powell River, at the Cracker Neck, Stock Creek and Guest River have each cut a picturesque gorge.

Powell Mountain which is the result of erosion acting on a broad arch of the rocks, which plunges toward the northeast, reaches its culmination in High Knob, 4,162 feet above sea level. From this high point the surface slopes gradually to the northeast and south in general conformity with hard beds of sandstone which dip in the same direction. West of High Knob the great arch has been breached by the cutting of Powell River, which has broadened its valley in the limestones and soft shale that form the core of the arch or anticline until it has a maximum width of 3 miles. In this valley are situated the town of Big Stone Gap and several villages that have sprung up on the line of the Southern Railway. The north limb of the

anticline, composed of steeply dipping beds of sandstone and conglomerate forms a rugged mountain that separates Powell Valley from the coal field on the north. This great mountain barrier extends southwestward from the vicinity of Norton far into Tennessee and its continuity is broken only at two places in a distance of 140 miles. One of these breaks in Lee County, known as Pennington Gap, was formed by the North Fork of Powell River cutting deeply into the upturned rocks, and the other is Big Stone Gap in Wise County, which has been cut by the main stream of Powell River.

Big Stone Gap through Stone Mountain has been one of the most important factors in the development of the Wise County coal field as it has afforded a water grade for the approach of two lines of railroad, the Southern and the Louisville and Nashville railroads, into this field. It also affords an easy route for a highway which now links the principal coal mining towns north of the mountain with the town of Big Stone Gap and other towns of the limestone region on the south.

The broad basin-like depression of Powell Valley, rimmed on three sides by high, steep slopes, is a surface feature in striking contrast to the plateaus and V-shaped valleys of the coal-field of Wise County. The valley country belongs to what physiographers have called the Appalachian Valley province. The view from the rim of the enclosing mountains at Little Stone Gap down into Powell Valley is the most impressive scene a traveler sees in passing over the main roadways of Wise County. The floor of the valley, as may be noted in this picture, is not flat but is a rolling country featured by rounded knobs and low linear ridges. Two streams — Butcher Creek and Beaverdam Creek, carry off the surplus water and they have cut shallow channels in the main valley floor. Both empty into the South Fork of Powell River in the vicinity of East Stone Gap. The divide separating these streams is chiefly a limestone ridge, which is characterized by sinkholes and small knobs, none of the latter being more than 50 to 100 feet high. Looked at from above, these minor topographic features of the valley appear insignificantly small in contrast to the enclosing rim that towers 1,400 feet above the general level of the valley floor.

In the middle distance a low mountain, known as Wallen Ridge, rises in the midst of the valley and grows higher and higher in a westerly direction, until it reaches its culmination in Elk Knob, $2\frac{1}{2}$ miles southwest of the town of Big Stone Gap. The ridge is unsymmetrical, having a gentle slope on the southeast side, corresponding in a general way with the dip of

the hard sandstone composing it, and a steep slope on the northwest side, extending down to Powell River which flows 1,600 feet below the level of its highest point.

The rolling country of the upper portion of Powell Valley is well adapted to farming and most of it is cleared and under cultivation. The soil in places, however, is rather poor, being a whitish clayey soil, derived from the weathering of black shale, and is much inferior to the limestone soil which is best suited for farming purposes. The distribution of kinds of soil in the valley country agrees closely with the outcrops of the underlying rocks.

The maximum relief in Wise County and the coal-bearing portion of Scott County is 3,000 feet. The largest interval recorded between bench marks is 2,829 feet, measured from High Knob in south central Wise County at an elevation of 4,162 feet, to Dry Creek, near Dungannon, in Scott County, at an elevation of 1,333 feet. Pine Mountain ranges in elevation from 2,407 feet at Pound Gap to 3,200 feet where the State boundary line turns south from the crest, and Black Mountain ranges from 3,500 feet to over 4,100 feet at the Double. High Knob of Powell Mountain is the highest point in Wise County. It is 1,557 feet lower than Mount Rogers in Grayson and Smith counties, the highest point in the State.

Drainage.—The drainage of Wise County and the adjacent portion of Scott County is divided between that flowing northeastward to Russell Fork of Big Sandy River and that flowing southward and southeastward into Clinch River. In either case the water reaches Ohio River, but in the former by way of Big Sandy River, and in the latter by way of Tennessee River. The divide between these two drainage systems is extremely circuitous, with a remarkable interfingering of branches tributary to the two master streams. The main components of the Clinch River drainage in this field are Powell and Guest rivers and Clinch River itself, which borders the southeastern edge of the coal field. Guest River empties into Clinch River where the boundary lines of Russell, Scott, and Wise counties intersect, and Powell River joins the same stream in Campbell County, Tennessee. In the Russell Fork basin, the principal streams are Pound River, including North and South forks, Birchfield Creek, and Cranesnest River, the two last mentioned joining at the boundary between Wise and Dickenson counties, two miles east of Birchfield school.

The larger tributaries of the two master rivers mentioned above are fed by innumerable smaller tributaries, ranging from intermittent brooks to permanent streams of fair size. A glance at the contour map of Wise

County accompanying this report reveals at once the intricate drainage pattern. The repetition of stream names in various parts of the country is also conspicuous. To avoid confusion in this report, in all cases of repetition, the stream into which the one in question flows will also be mentioned, such as Dry Creek of Stony Creek, or Dry Creek of Clinch River.

Many of the streams in this region carry very little water except in times of rains or the melting of snow. Nearly all the smaller streams dry up and even the major streams, such as Pound, Guest and Powell rivers, dwindle to insignificant proportions during periods of prolonged drought. Water from heavy rains is quickly carried off, as the streams in most part have steep gradients which, with the sandy soil and wooded slopes, prevent the heaviest rains from giving rise to serious floods. In view of the rapid run-off of the water, the larger towns, in order to conserve a water supply, have been forced to construct reservoirs by damming the streams. Clinch River is the largest stream in the territory and carries a fairly large volume of water all the year round. The waters of a few of the streams on the south slope of Powell Mountain flow in places for miles in a mantle of water-worn boulders, which conspicuously marks the course of the stream, but conceals the water, a fact which gives rise to the popular term "dry creek."

Springs are fairly abundant and many underground streams of considerable volume come to the surface in the limestone country. The majority of the springs are persistent and do not dry up except in times of prolonged drought. The rainfall in Wise County is large, the annual precipitation averaging about 47 inches.

Accessibility of the coal field.

The development of a new coal field or the extension of workings in an old field depends almost entirely upon its accessibility to railroads. The railroads in turn must follow the valleys, as the valleys are the natural channels of ingress and egress to any hilly or mountainous field. In the Wise County field two great barriers, Pine and Stone mountains, practically inclose the coal field. Nature, however, in carving the Big Stone Gap, has provided a natural gateway to and from the south, the west, and the east, the advantage of which the railroads were quick to appreciate. The gorge of Guest River, long recognized as a possible railroad route to and from the basin, will soon be the site of another railroad connection to the field, as the construction down that stream of an extension of the Interstate Railroad to connect with the Carolina, Clinchfield and Ohio Railroad at Bangor is now being undertaken.

The Clinch Valley Division of the Norfolk and Western Railway enters Wise County at St. Paul. It leaves Clinch River west of St. Paul, and climbs by a steep grade, several tunnels and high trestles, to the open portion of Guest River valley west of Coeburn, reaching Norton its southwestern terminus. The Louisville and Nashville Railroad (Cumberland Valley division) follows Powell River from the county boundary through Big Stone Gap to Dorchester and crosses the low Powell-Guest rivers' divide into Norton. The Southern Railroad (Appalachian division, formerly the South Atlantic and Ohio and later the Virginia and Southwestern) enters from the southeast, through Big Stone Gap to Appalachia, and turns west into Lee County. The Carolina, Clinchfield and Ohio Railroad from Spartanburg, S. C., to Elkhorn City, Ky., follows Clinch River along the southeast border of the county crossing the Norfolk and Western at St. Paul. Towns on Callahan Creek, Roaring Fork, upper Powell and Guest Rivers are served by branches of the Interstate Railroad, the main line of which parallels the Louisville and Nashville Railroad from Norton to Appalachia. The Norton and Northern Railroad is a short line running up Yellow Creek Valley, connecting Norton with Wise.

The bulk of the coal finds its way to market over the Norfolk and Western, and Southern railways. Over the former, it is shipped, via Bluefield, to eastern and northern cities and over the latter it goes, via Moccasin Gap, to southern, eastern and northeastern points. Coal shipped by the Louisville and Nashville Railroad, goes via Middleboro, Ky., to points west and southwest.

The entire southern half of Wise County is opened by these railroads for mining development. The northern half, the Pound River drainage basin, does not possess a single railroad, to urge the exploitation of its coals. A logging road formerly ran north down Indian Creek from Glamorgan to Pound River and up Laurel Branch to Pine Mountain but it has been torn up. Several surveys have been made up Pound River from the Carolina, Clinchfield and Ohio at the Breaks of Sandy, but no construction has yet been attempted.

The coals of the Lee formation on Powell Mountain are not so accessible as are the coals to the north and east. The streams here have steep gradients including falls in many places and offer few natural advantages for the location of a railroad. A tramway for lumber has been built from Fort Blackmore seven or eight miles up Stony Creek and its branches, and another was built up Little Stony Creek from Dungannon. Some coal is carried out by the latter for shipment, but none from the former. There

is very small likelihood at present of a standard-gauge spur of the Carolina, Clinchfield and Ohio Railroad on Clinch River being built up either creek. Indeed so much does the surface features retard development here that it is likely to be many years before the Powell Mountain coals, in view of their present inaccessibility, will be profitably worked.

GEOLOGY

STRATIGRAPHY.

GENERAL STATEMENT.

The rocks of this country have been divided by geologists into major systems, which in turn are subdivided into series, groups, formations, and members. A system of rocks includes all those that have been laid down within a single period of geologic time; for example, the Devonian system and the Carboniferous system. A series of rocks includes all those that have been formed within a single epoch of geologic time; for example, the Mississippian series and the Pennsylvania series. Systems and series are frequently subdivided into groups, the groups into formations, and the formations into members. The division into formations and members is based largely on the lithology of the rocks. In order that the reader may have a general picture of the division of time as the geologist sees them and understand the relationship of the rocks exposed in Wise County to the entire time scale, the geologic table as accepted by the United States Geological Survey, is given below:

<i>Era.</i>	<i>Period.</i>	<i>Epoch.</i>
Cenozoic	{ Quaternary	{ Recent Pleistocene
	{ Tertiary	{ Pliocene Miocene Oligocene Eocene
Mesozoic	{ Cretaceous	
	{ Jurassic	
	TRIASSIC	
Paleozoic	{ Carboniferous	{ Permian Pennsylvanian Mississippian
	{ Devonian	
	{ Silurian	
	{ Ordovician	
	{ Cambrian	
Proterozoic and Archeozoic	{ Algonkian	
	{ Archean	

The rocks exposed in the territory described in this report range in geologic age from the Cambrian up into the Pennsylvania, and they are described in stratigraphic sequence from the lowest to the highest. In general, they may be divided into the coal-bearing and the non-coal-bearing rocks. The recognized base of the coal-bearing rocks in this field is the base of the Pennsylvanian. A few thin and inconsequential coal beds occur in the Mississippian, but they are of no economical value.

POST-MISSISSIPPIAN ROCKS.

Pennsylvanian Series.

GENERAL STATEMENT.

The rocks of the coal-bearing portions of Wise and Scott counties, exclusive of residual soil and alluvium, belong to the Mississippian and Pennsylvanian series of the Carboniferous system. The rocks in the coal field are widely covered by a thin mantle of residual soil, and many of the valleys are filled with alluvium, but these surficial deposits are not extensive or important enough to warrant mapping. The bed rock is usually well exposed in the headwater channels of streams and on the spurs.

The Pennsylvania series in Wise and Scott counties consists of sandstone, shale, clay and coal beds and is about 5,750 feet thick. These rocks, all of Pottsville age, were divided by Campbell¹ into the following formations named in ascending order; Lee conglomerate, Norton formation, Gladeville sandstone, Wise formation and Harlan sandstone. The Lee formation was named for Lee County, but is typically developed in Big Stone Gap. The Harlan sandstone is best developed on Big Black Mountain and hence was named for Harlan County, Kentucky. The other formations were named for type localities in Wise County. The character of the rocks, the sequence and relative thickness of the formations, and the number, position and succession of coal beds are shown in Fig. 4. This section is generalized and shows the average section of the formations, rather than any particular measured section.

The formations are differentiated largely on a lithologic basis. Thus the Pennington shale consists largely of shale which may be identified generally by its red and green colors. The Lee formation consists of massive

¹ Campbell, M. R., *Geology of the Big Stone Gap coal field of Virginia and Kentucky*; U. S. Geol. Survey Bull. 111, pp. 33-36, 1893.

GENERALIZED SECTION SHOWING COAL BEDS
OF THE NORTON AND WISE FORMATIONS

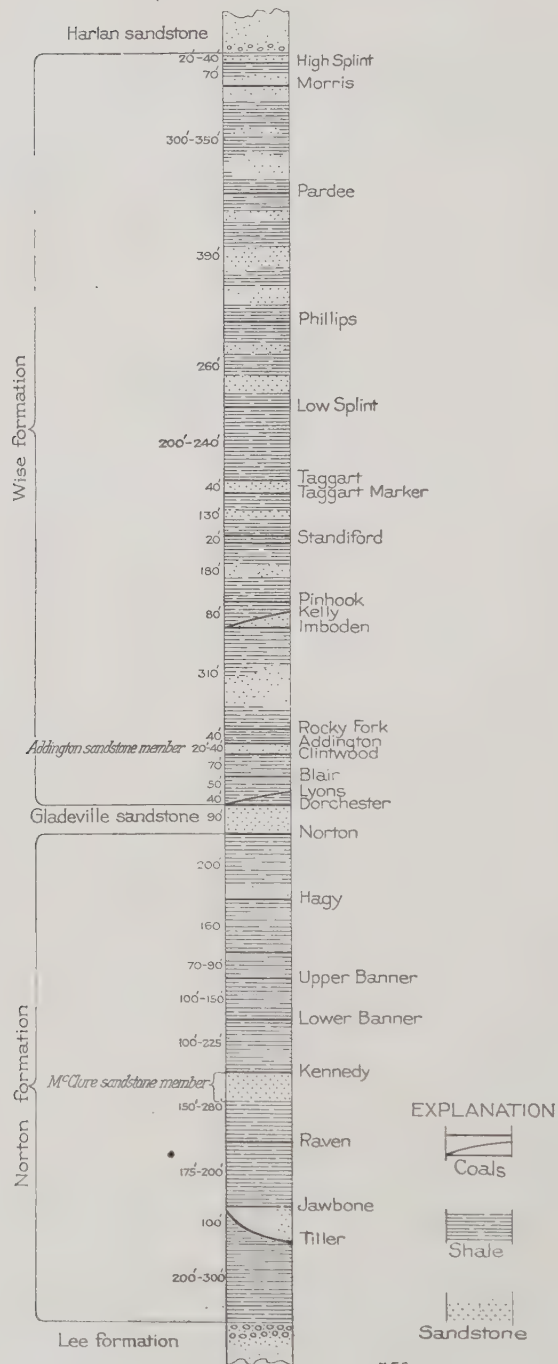


Fig. 2.—Generalized section showing coal beds of the Norton and Wise formations.

beds of sandstone containing in places layers of rounded white quartz pebbles, $\frac{1}{8}$ to 1 inch in diameter. The Gladeville is a massive bed of coarse white sandstone. The Harlan sandstone is featured by the great thickness and massiveness of the basal sandstone in the formation. The intervening Norton and Wise formations consist of a heterogeneous mass of rocks, largely shale, clay, soft sandstone and coal beds. For purposes of identification and correlation the coal beds and sandstones are the most important members of the Wise and Norton formations, the latter particularly being traceable in parts of the field for a distance of many miles. As the region is one of sharp relief, surficial materials rarely conceal the outcrop of sandstone occurring in the ridges. The coal beds of the Pennsylvanian series here described are of such economic importance that they are described separately and in detail in later sections of the report.

The Pennsylvanian rocks of this region are composed of nearly equal parts of sandstone and shale, with sandstone more abundant at the base and top of the section. Much of the sandstone is coarse, hard and conglomeratic, such as the massive beds of the Lee, and the hard sandstones of the Gladeville and Harlan. These beds make prominent cliffs and ledges, the weathered surface acquiring a dull gray color. On freshly cut surfaces this type of sandstone is white to pinkish but stains readily from iron that is usually present in considerable amount. The greater mass, but less conspicuous type, of Pennsylvanian sandstones is a fine—to coarse—grained thin-bedded rock that on weathering has the appearance of sandy shale. It is usually cross-bedded and contains much clay indicating irregular and disturbed conditions of deposition. The sandstone is usually friable from the presence of considerable decomposing feldspar. Quartz and mica are present in large quantity. Upon disintegration this type of sandstone furnishes a micaceous sandy soil; usually quite fertile from the clay present.

Shale is a common rock type of the Pennsylvania series. It is usually sandy grading through sandy shale to sandstone, and more rarely is a true clay shale. The common color is drab, and yellow and, to a lesser extent, red and brown. Hard shale, usually found near coal beds, is steel-gray in color with a bluish tinge.

A thin fossiliferous limestone was seen in the upper part of the Pennsylvanian rocks in Black Mountain. The bed is 8 inches thick and lies 210 to 225 feet above a coal described as the Phillips bed. This is the only limestone found in the coal-bearing rocks of Wise County.

LEE FORMATION.

The Lee formation is composed of three thick, massive sandstone members that usually are markedly conglomeratic and are separated by shale and thin-bedded sandstones containing several thin coal beds. To the upper conglomerate Stevenson in 1881 applied the name "Bee Rock." The middle conglomerate is here named the Bald Rock conglomerate member from a prominent feature in the vicinity of Miller Yards, about 4 miles west of Dungannon, locally called the Bald Rock. The lower conglomerate member is herein referred to as the basal sandstone of the Lee. The three beds are hard, massive, and the most prominently mountain-making sandstone beds in the Carboniferous system of rocks in this field. The formation is named for Lee County, Va., although the type section as described by Campbell is in Big Stone Gap.

The Lee formation is 1,530 feet thick at Big Stone Gap and 1,800 feet thick at Little Stone Gap. The formation thins rapidly to the west and northwest and is but 784 feet thick in a deep boring put down on Cranesnest River, near Birchfield Creek. On the western margin of the Appalachian coal field, in Menifee County, Ky., Crandall¹ describes the conglomeratic sandstones of the lower Pennsylvanian as ranging in thickness from 20 to 100 feet.

The "Bee Rock" of the Lee is a massive conglomerate 95 to 120 feet thick. It makes sharp overhanging crags along the entire north slope of Powell, Stone, and Little Stone Mountains west of Tacoma. The bed is the resistant sandstone that makes much of the surface of Powell Mountain South of Coeburn, Tacoma and Ramsey. The middle and lower sandstone members are usually considerably thicker than the top member and are conglomeratic in zones. The Bald Rock is 200 feet thick in Big Stone Gap and 160 feet thick in Little Stone Gap. The basal conglomerate ranges in thickness up to 250 feet. The three beds are composed of hard, clean sandstone, with pebbles of purest white quartz. The sandstones of the Lee as a rule are much less arkosic than those of the higher formations and contain a much larger proportion of quartz grains.

A conglomeratic sandstone that forms a low hogback in the lower slope of Pine Mountain in Wise County has all the characteristics of a Lee conglomerate member and was called the "top of the Lee" in reports by Stone and Butts previously mentioned. Work in Dickenson County and farther northeast, however, confirmed by a study of fossil plants by David

¹ Crandall, A. L.: Kentucky Geol. Survey, vol. II, new series, pp. 353-357.

White, has shown that this bed is the rock directly beneath the Kennedy coal bed in the Norton formation, and that its top is 400 to 550 feet above the top of the Lee. This bed is here called the McClure sandstone for McClure River in central Dickenson County. The sandstone outcrops extensively and typically along the banks of McClure River from Caney Creek south to Sandy Ridge, and the towns of Nora and Stratton are underlain by it. The Carolina, Clinchfield and Ohio Railroad runs along the outcrop of this bed and McClure River for a distance of approximately 11 miles.

The rocks between the thick sandstone beds are shale, sandy shale and a very small percentage of clay and coal. The shale is soft and weathers out readily between the beds of sandstone where the rocks are turned up at a high angle, resulting in the formation of narrow valleys with one steep or overhanging wall.

NORTON FORMATION.

The mass of sandstone, shale and coal beds lying between the Lee formation and the Gladeville sandstone are grouped into a formation to which the name Norton was given, for Norton, the largest town in Wise County. The formation crops out in two principal belts or zones; one just north of Powell, Little Stone and Stone mountains, and the other south of Pine Mountain. The formation consists of alternate beds of sandstone and shale interbedded with coal.

The Norton formation varies in thickness from 1,300 to 1,500 feet, with the thinning in a northerly direction. The formation is 1,475 feet thick in the vicinity of Coeburn and 1,460 feet in the southwestern part of Dickenson County. The disturbed condition of the rocks along the foot of Powell and Stone mountains west of Tacoma has been the cause of many discrepancies in published accounts of the thickness of this formation. Many low folds in the main coal basin have also added to the difficulty of correctly identifying and measuring this formation. The name Norton was given to the formation by Campbell under the impression that the Gladeville sandstone is the coarse sandstone capping the ridge back of the town of Norton and hence that the formation in question is at the surface in the entire town site. Recent work has shown this conclusion to be in error, and it is now known that the Gladeville sandstone instead of capping the ridge is below the surface in all that part of the town lying west of the railroad and consequently the town is in reality on the Wise formation instead of the Norton as was originally supposed. The only rocks belonging to the Norton formation near the town are those between the railroad and

the uppermost conglomerate of the Lee formation, and these rocks are practically on edge as they were upturned in the great fold of Powell Mountain. As the full thickness of the Northern formation may not be present at Norton, the type locality for measurement and study of this formation should be taken farther east, where the dips are more gentle and the rocks are more fully exposed. These conditions prevail at the towns of Coeburn and Virginia City and consequently these places may be taken as the type localities. No satisfactory measures of the thickness of the Norton formation was made on the slope of Pine Mountain because on very long dip-slopes it is extremely difficult to measure thickness accurately.

Several sandstone beds in the Norton formation are persistent and can be traced without great difficulty (fig. 2). Among the most easily identified beds is the McClure sandstone which is associated with the Kennedy coal bed, near the middle of the formation. The coal is underlain everywhere by coarse sandstone, 50 to 200 feet thick, that forms ledges and, especially along Pine Mountain, high cliffs. Generally the McClure sandstone is an ordinary coarse sandstone, but on Pine Mountain it is sparingly conglomeratic. A sandstone of much less prominence and importance as a marker is found between the Tiller and Jawbone coal beds, both of which lie in the lower part of the Norton formation. Another massive sandstone lying 100 to 150 feet below the Gladeville sandstone has a conspicuous outcrop in east-central Wise County. It overlies a coal bed known as the Hagy. The sandstone beds described above are of the Gladeville type,—hard, gray and quartzose.

Shale is the predominating rock between the prominent sandstone members of the Norton, but soft micaceous sandstone is not uncommon. Taken as a whole, however, sandstone constitutes less than $\frac{1}{4}$ of the Norton formation. The shale is largely clayey and non-fossiliferous, except for fossil plant found in association with the coal beds. Clay is not common, and limestone or calcareous shale has not been found in the Norton formation.

GLADEVILLE SANDSTONE.

The most important key-rock in Wise County above the "Bee Rock" of the Lee is the Gladeville sandstone. The bed received its name from Gladeville, the former name of the town of Wise, where the sandstone is well exposed. Here the bed is a hard gray quartzose sandstone ranging in thickness from 90 to 110 feet. It makes the plateau upon which the town of Wise stands, and which extends eastward as far as Steele Fork. Southwest and west of the town many of the ridges are capped by this

sandstone, but in small outcrops on ridge tops it is sometimes difficult to distinguish it from other sandstones which locally attain its thickness and characteristics. To the east, Sandy Ridge, in large part, is held up by this massive stratum. In the central and eastern part of Wise County the bed is not conglomeratic, but in the western part, as shown by a deep boring on Preacher Creek, the Gladeville has a thickness of 130 feet with the lower 50 feet conglomeratic. It extends westward beyond the limits of the county and makes high cliffs of conglomerate on the North Fork of Powell River in Lee County. The Gladeville sandstone does not hold its massive character throughout the county for in some places the logs of test holes show only sandy shale. A few borings show thin coal beds in the Gladeville.

The Gladeville sandstone at Wise is a fairly pure quartzose sandstone. To the north it is more clayey, contains feldspar and mica, and is iron-stained. It does not resist weathering so effectively in northern Wise County, and breaks down into a coarse sandy soil. The sandstone at Wise is water-bearing and supplies many wells of the town and vicinity, but its area of intake is small and the supply of water is not large.

WISE FORMATION.

The Wise formation consists of a great mass of coal-bearing rocks lying between the Gladeville sandstone and Harlan sandstone, including beds of sandstone, shale, clay, coal and one or more thin limestones. The formation is fully exposed in this field and was named for Wise County. The rocks of this formation do not differ essentially from the rocks of the Norton formation, but the coal beds are more abundant and, in one case at least, considerably thicker than the coal beds of the Norton. The Wise formation has an extensive outcrop in the slopes of Black Mountain, in west, central, and north-central Wise County. Its outcrop covers at least half of the area of Pennsylvanian rocks in Wise and Scott counties.

The Wise formation in western Wise County is 2,300 feet thick, but it thins gently to the northeast as shown by a section 2,070 feet thick measured by Butts on the South Fork of Pound River.

The rocks of the formation are about one-third sandstone, but few of the beds of sandstone are persistent enough to make good horizon markers. The beds best adapted to this purpose are three in number—a hard white sandstone, 20 to 50 feet thick, about 180 to 200 feet above the base of the formation, and here named the Addington sandstone member—a thick coarse micaceous sandstone just above the noted Imboden coal bed; and a

hard fine-grained sandstone bed lying between the Taggart and Taggart Marker coal beds and about 1,000 feet above the base of the Wise formation. Of these beds the Addington sandstone is undoubtedly the best marker of the three. It is named for Addington, a station on the Interstate Railroad on Rocky Fork, $1\frac{1}{2}$ miles south of Glamorgan, where it forms great ledges, resembling those of the Gladeville sandstone in its best development, but is not so thick. The Addington sandstone is less valuable as a horizon marker in the western part of the field, because a similar sandstone is found below the Imboden coal bed, and both change their character considerably within the field. The sandstone between the Taggart and Taggart Marker coal beds is of value as a marker only in the western part of the field. Taken as a whole, however, the Wise formation presents a monotonous repetition of beds of sandstone and shale, no one of which is of sufficient lithologic individuality and continuity to be worthy of representation on the geologic map.

The shale of the Wise formation in large part is drab in color and weathers to a yellow sandy soil, but a thick bed of reddish brown shale which weathers to a thick, clayey, and fertile soil lies beneath the sandstone below the Imboden coal bed. Many beds of clay occur in the Wise formation. They are seldom mono-colored, but in many places show beautifully tinted laminae curved into delicate and intricate patterns.

Marine fossils, *Spirifer* and *Productus*, have been found at two localities and at two horizons. One locality is the bank of the South Fork of Pound River a short distance west of the point where the river is crossed by the Norton pike. The horizon of the bed containing them is about 60 feet below the Imboden (Lower Bolling) coal. The second locality is a cut on the pike a short distance north of and about 50 feet below the summit of Fox Gap at the head of Guest River. The horizon is believed to be that of the Low Splint coal, for marine fossils are reported by Crider¹ in the roof of that bed in Kentucky.

In Kentucky on the west side of Black Mountain and probably only a mile or two distance from Virginia, a fossiliferous limestone reaching a thickness of 3 feet is present 50 to 100 feet above the Pardee coal. This bed is said by Hodge² to have been detected in Virginia only on Pot Camp

¹Crider, A. F., The coals of Letcher County, Kentucky Geological Survey, 4th ser. vol. 4, Pl. 1, p. 21, 1916.

²Hodge James M., Report on the Upper Cumberland Coal Field, Kentucky Geological Survey, Bull. 13, Serial No. 16, p. 27, 1912.

Fork where it is more nearly a sandstone than a limestone. The chief interest in these occurrences of marine fossils is the light they cast on the geographic conditions of the region during the time of the deposition of the Wise formation and their value in a correlation of the coal beds. The region was evidently a vast swamp near sea level. During the time of the accumulation of the vegetal matter of the coal beds the region was slightly above sea level for the plants were such as could grow only on land or in fresh water swamps where their remains were protected from decay by being partly or wholly submerged by water, as in a modern peat bog. At times, however, the region, was in part at least submerged by the ocean water, as proved by the presence of the fossil remains of marine organism, as described above.

HARLAN SANDSTONE.

Black Mountain and its many high spurs radiating into western Wise County, are capped by a massive cliff-making sandstone, in places conglomeratic, and 40 to 60 feet thick. This bed, overlying the High Splint coal near the top of the Wise formation by 30 to 40 feet, is regarded as the basal bed of the Harland sandstone. The formation is named for Harlan County, Kentucky, and is called "sandstone" because of the great predominance of sandstone in the formation. Coal is reported at two horizons in the formation, one about 70 and the other 270 feet above the base of the formation.

The lowest part of the basal sandstone consists of about 20 to 30 feet of arkosic¹ sandstone which weathers into layers 1 to 2 inches in thickness. The bed makes a striking wall along the ridge crests, and in many places it has, owing to the horizontal layers of differential weathering, the appearance of human artifice. Above this "wall rock" lies a very massive conglomeratic sandstone about 100 feet thick, that forms at many places impassable cliffs. The bed is extremely hard and pinkish on fresh surfaces. At the head of Ison Rock and Looney ridges this bed stands out with extraordinary prominence.

At some places on the crest of Black Mountain as much as 750 feet of sandstone and shale overlie these basal members. Above the lowest sandstone beds just described lie 550 feet of sandy shale and thin-bedded sandstone. These sandstone beds are fossiliferous, being full of plant remains that weather out in profusion. A thick bed of sandstone makes the high

¹ A *pure* sandstone contains only quartz, an *arkosic* sandstone contains the mineral feldspar in addition to quartz. The feldspar weathers more readily than quartz and an arkosic sandstone is therefore usually more friable than pure sandstone.

summit of the Double, and sheds great blocks of sandstone down the mountain slope. North along Black Mountain, higher in the formation, a coarse white sandstone, 60 feet thick, crops out 780 feet above the base of the formation. A thin band of shale with a water seep, indicating the presence of coal, and a 40-foot bed of thick-bedded sandstone mark the top of the Harlan formation in Wise County and are the highest rocks stratigraphically in the region.

Quaternary System.

ALLUVIUM.

The smaller streams flowing down the steep slopes of Wise and Scott counties have great cutting and transporting powers. Soil, sand, and clay, washed into these streams, are carried along with the fragments of sandstone and shale derived from stream erosion. Where a headwater branch enters its master stream, the gradient of the stream beds decreases, and much of the stream's burden is dropped. Alluvium is the term applied to the unconsolidated mass of sand, clay, gravel, and rock fragments so deposited. Alluvial deposits, making narrow floodplains, are found to a limited extent in this territory, the chief accumulations occurring along Clinch, Pound, and lower Powell rivers. The alluvium that has collected in such large quantities along Clinch River is a fertile sandy loam.

SOIL.

The soil of this region is the direct result of the weathering and disintegration of underlying formations and its character is therefore largely dependent upon the nature of the parent rock. The Pennsylvanian rocks give rise chiefly to a sandy loam due to the great amount of sandstone and sandy shale in the coal measures. The best soils of the region lie on the flat-topped ridges and near the base of the slopes or in general where erosive action is not so strong. Thus on Sandy Ridge and the Flatwoods of Powell Mountain, the soil is deep and rich and many small tracts are cleared and under cultivation. The Flatwoods country is especially fertile. On the hillsides the soil is good in localities, but often mixed to such an extent with sandstone debris as to render it unsuitable for farming. Some slope-farming is carried on in Wise County but once a steep slope is cleared, it is rapidly denuded of its soil mantle and the site must be abandoned for reforestation.

CORRELATIONS WITH ADJOINING AREAS.

The correlation of the coal beds of Kentucky with those of Wise County across the Pine Mountain fault was accomplished by Hinds and the results were published in Bulletin XVIII of the Virginia Geological Survey on the geology and coal resources of Buchanan County. Detailed private surveys in southeastern Pike County, Kentucky, confirmed Hinds' conclusions as did also the examination of fossil plants by David White.

The correlation of the coal beds of Lee County, Virginia and Harlan County, Ky., with those of Wise County depends largely on several important correlations of coal beds made within Wise County itself during the course of the present survey. As the result of detailed examinations at the head of Black Creek, Campbell, assisted by the writer, established the equivalence of the noted Imboden bed with the "Lower Bolling" bed of Butts' report on the Pound quadrangle. The second major correlation is that of the Dorchester bed at Dorchester with the Glamorgan bed of Butts. With these major correlations in hand the problem of tying in the inter-mediated beds has been greatly simplified. The position of the Jawbone bed near the base of the Norton and its relation to the top of the Lee has been accurately determined in eastern Wise County, and the identification of the "so-called Imboden" as the Raven bed follows at once. Following the correct identification of coal beds in Wise County, the correlation of these beds with the ones found by Giles in Lee County, Virginia and by Hodge in Kentucky, is made possible. Giles¹ correlates No. 5 bed of the Pocket in Lee County, with the Keokee bed of Keokee, and accurate private surveys establish the identity of the Keokee bed with the Taggart of Wise County. On the basis of this correlation coal bed No. 1 of the Pocket would be equivalent to the Imboden, No. 6 to the Low Splint, No. 10 to the Pardee and No. 12 to the High Splint. Coal bed No. 3 of the Pocket is thought to be the same as the Wilson bed of the Keokee district and equivalent to one of the Stanford coal beds of Wise County.

Carrying the correlation of coal beds across Black Mountain has been relatively simple and the section given by Hodge² for the headwaters of Clover Fork, Harlan County, Ky., is essentially the same as that measured on the east side of the mountain. The conglomeratic sandstone of Hodge

¹Giles, A. W., The Geology and Coal Resources of Lee County, Virginia, unpublished manuscript.

²Hodge, James M., Report on Upper Cumberland Coal Field, Kentucky Geological Survey, Bulletin 13, Serial No. 16, 1912, p. 3.

is the Gladeville sandstone and the Dorchester bed in his section is probably the Clintwood bed of Wise County. The Dean bed is everywhere identified by its clay parting and the limestone bed by the proximity of an overlying fossiliferous limestone. Mining operations have since verified the correlations of Hodge, as mine entries have been driven under Black Mountain into Kentucky in both the Taggart and Pardee coal beds.

The Haddix coal bed is overlain by a thin fossiliferous impure limestone which Crider notes¹ "is apparently the only fossiliferous limestone in the upper strata of the Pennsylvanian series in Letcher County." The correlation of the Haddix with the limestone coal of Hodge and the Pardee bed of Wise County is firmly established. The correlation of the Upper Elkhorn with the Taggart has been established by Hinds in his work in Buchanan County, and Pike County, Ky. The Fire Clay bed of Crider has the characteristic clay parting of the Dean coal of Hodge. Above the Flag coal bed Crider² describes a massive cliff-making sandstone that is probably the basal bed of the Harlan sandstone, as known in Wise County. On the strength of the foregoing ties the indicated correlation of intermediate beds has been made largely on relative intervals.

Further correlations of the Kentucky coal beds with the Virginia coal beds, on the authority of Hoge, Crider, L. A. Bilips,³ and others are given as follows: the Taggart coal bed with the "C" bed, (at Lynch), the McConnell, the Creech, and the Mingo; the Low Splint, with the "E" bed; the Phillips, with the Dean, Fire Clay, Poplar Lick, No. 4, Hyden, and Flatwoods; and the Pardee, with the Haddix, Limestone, Hignite, and Lynch. Bilips correlates the "A" bed at Lynch with the Harlan bed of Hodge, the Imboden bed of Wise County and with the Hance bed. The "A" bed, according to Bilips, lies 220 feet below the Taggart, an interval less than one-half the Imboden-Taggart interval found by Hodge on Clover Fork or on the east side of Black Mountain in Wise County, and the correctness of the "A"-Imboden correlation is greatly questioned.

The coal beds of northern Wise County have been traced into Dickenson County and thence northeastward into Buchanan County and West Virginia. The most important correlation is that of the Imboden with the Campbell Creek coal or No. 2 gas coal of the West Virginia Geological

¹ Op. cit., p. 36.

² Op. cit., p. 38.

³ Division engineer, United States Coal and Coke Company, Lynch, Ky.; personal communication.

Survey. This bed is locally called the Lower Elkhorn, Lower Marrowbone, Warfield, Freeburn, Burnwell, Van Lear, Vulcan, Majestic, and Upper War Eagle in Pike County, Kentucky, and Mingo County, West Virginia. The Lower War Eagle bed of Tug Fork is the same as the Hagy bed of southwest Virginia. Hinds refers the Taggart or Upper Elkhorn coal bed to either the Alma or Lower Cedar Grove beds of West Virginia. The Eagle bed, prominent in Dickenson County but of no importance in Wise County, is locally known as Middle War Eagle and Mohawk on Tug Fork.

GEOLOGIC STRUCTURE.

DEFINITION.

By the term "geologic structure" is meant the attitude or lay of the rocks. The rocks of Wise County, consisting of limestone, shale, sandstone, clay and coal beds, are all of sedimentary origin and were originally laid down in a horizontal or nearly horizontal position. Following the deposition of the materials now forming the rocks, compressive stresses developed in the crust of the earth which exerted great pressure on the rocks, folding them into anticlines and synclines where the pressure was of moderate intensity and shearing them and forming faults where the pressure was greatest or where it was exerted at right angles to the bedding planes. In passing from the coal field at Appalachia through Big Stone Gap, one is generally impressed with the idea that he passes from a region in which the rocks are flat or structureless to one in which they are highly tilted, forming pronounced structures. It must not be inferred, however, from this statement that only tilted rocks exhibit geologic structure and that flat-lying rocks are without structure, for this is not the case. Structure, as defined above, is the "attitude" of the rocks and hence it must apply to rocks that are nearly horizontal as well as to rocks that stand on edge.

As geologic structure controls the attitude of a coal bed and as it has had a profound effect upon the work of the streams, it is one of the principal geologic conditions that has helped to give the surface its present configuration, and as the present configuration is an all-important factor in the development of coal mines, the more important features of this structure will now be described in some detail.

METHODS OF REPRESENTATION.

General statement.

As the rocks composing the earth's crust are seldom found in a strictly horizontal position, one of the most important duties of a geologist in

making a field examination is to determine the attitude of the rocks and his second duty is to portray in his report, that attitude so that everyone who reads the report may be able to have a clear conception of the geologic structure, as it is generally called. There are two general methods of representing structure, both of which are useful and both used in this report. These are known as (1) representation by means of structure sections, and (2) by means of structure contours.

Structure sections.

Structure sections are supposed to show the lay or attitude of the different strata as they would appear in the side of a deep trench dug across the country, generally in a straight line. Such sections give the reader a clear picture of the dip of the beds, the folds into which they have been thrown, and the effect of particularly hard rocks in forming hills, ridges, and mountains. The chief defect, however, is that each section shows the geologic structure along a single line only and frequently gives no clue to complications that may be present in adjacent localities. To the engineer they are qualitative but not quantitative in that they suggest what the geologic structure may be but give him no absolute data by which he can determine it at any particular point off the line of the section.

Structure contours.

The most important work that a geologist can perform in a coal field is to determine the depth of all important coal beds beneath the surface and the direction and amount of their dip. If this is done and represented in such a way that the engineer may interpret it for every point in the field, he will have little difficulty in prospecting for the coal beds that lie beneath the surface, in laying out new mines and in so planning his surface work as to mine the coal and get it ready for shipment at the lowest cost possible.

The most effectual way of meeting these needs of the mining engineer is for the geologist to represent the geologic structure of the field by what is generally termed structure contours. These are lines so drawn that each one connects points of equal elevation on some particular and recognizable reference bed. Surface contours show the size and shape of hills and valleys on the surface of the ground and structure contours show the "hills and valleys" of the surface of an underground stratum of rock, as they would appear if the overlying rocks were stripped away.

In the Wise County field the great length of the stratigraphic section involved has made it impractical to contour the whole area on any one bed

and it was decided therefore that it would be of much greater practical value to use different beds in different parts of the field or four in all for this purpose. The reference strata used in this report are as follows: In western Wise County the Imboden coal bed; in central and northern Wise County, the top of the Gladeville sandstone; in eastern Wise County, the Upper Banner coal bed; and in southern Wise and northern Scott counties, the top of the Lee formation. The contour interval—the vertical distance between the horizontal planes of two successive contours—used in this report is 50 feet. The major intervals between the four sets of structure contours are all multiples of 50 feet and hence there are no breaks in the contours in passing from one reference bed to another, but there is a break in the elevations above sea level. The contours on the different beds are indicated by lines of different colors and the figures representing elevations are for the bed upon which the contour is drawn. From the structure contours the magnitude of the dip of the reference bed in feet per mile and also the direction of dip can readily be ascertained from the map. The dip so determined for the reference bed would apply equally well to other beds of rock were it not for the fact that the intervals between the beds of the various formations are not constant and consequently the beds are not strictly parallel, but in a general way the difference is not so great but that the structure determined for one particular bed may be regarded as applying also to others either above or below it. If the beds thin in the direction of the regional dip, the dip of beds above the datum surface will be greater than that indicated on the map and the dip of beds below the datum surface will be less; and if they thicken in the direction of the regional dip the converse will be true.

A second important use for structure contours is to determine on the map the position of the outcrop of any bed or to calculate the depth of the bed below the surface where it is not exposed. The simplest case of this kind is the one in which the bed in question is the key rock upon which the structure contours are drawn. Thus if it is desired to find a point at which the Upper Banner coal bed crops out on the sides of the valley of Toms Creek at a certain place, it is necessary to note only the elevation of the Upper Banner structure contour, through or nearest the point, and find where it intersects a surface contour of the same elevation. Such a point will then lie on the outcrop of the bed (A C and E fig. 3). If all the surface contours at or near the point are higher than the structure contours (B fig. 3) the bed will lie below the surface and the distance necessary to drill for it can readily be obtained by subtracting the structure contour ele-

vation from the surface elevation at that point. If all of the surface contours at or near the point lie below the structure contour (D fig. 3) it is at once obvious that the position of the bed is above the surface and that the bed has been eroded away. If it is desired to find the position of a higher

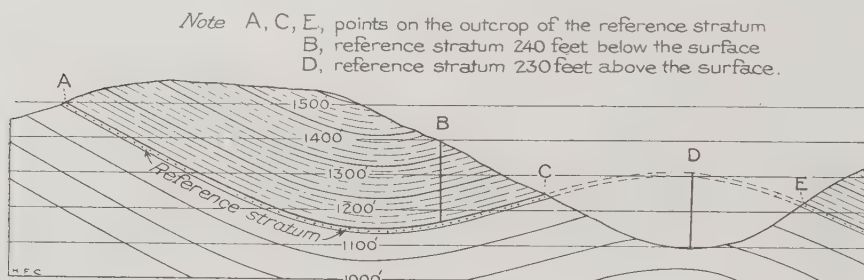


Fig. 3.—Diagram to illustrate the meaning and use of structure contours.

or lower bed it is only necessary to add or subtract the interval between the bed in question and the reference bed and proceed as in the case just described.

If, for example, it is desired to find the depth below stream level of the Kennedy coal bed at the town of Toms Creek, the following procedure would apply. Locate the intersection of the stream and the nearest Upper Banner structure contour on the geologic map. The Upper Banner contour indicates that the Upper Banner coal is here at an elevation of 2,200 feet above sea level, and the surface contour indicates that stream level is 2,025 feet above sea level. The Kennedy coal bed lies about 325 feet below the Upper Banner coal bed (see fig. 3); hence its elevation, above sea level is 2,200 feet minus 325 feet, or 1,875 feet. The difference, therefore, between the surface elevation or 2,025 feet and the Kennedy coal elevation or 1,875 feet is 150 feet, or in other words the Kennedy coal bed at Toms Creek is about 150 feet below the surface. For a coal lying above the Upper Banner the procedure is identical except that the interval is added to the elevation of the Upper Banner contour.

The usefulness of structure contours naturally depends upon the accuracy with which they are determined. There will always be a certain amount of uncertainty in contouring a bed concealed by overlying rocks and the possible sources of error may be large, but if many well logs are available the error in the location of the contours may be very small. For eastern, central, and western Wise County abundant material is available,

and it is believed that errors of as much as 50 feet are rare. The northern and southern sections of the region have not been drilled or explored so thoroughly and the contouring of necessity does not attain so high a degree of accuracy. No contours are drawn in the areas of greatly disturbed rocks, as along the north face of Stone and Little Stone Mountains, or in the area of upturned rocks adjoining the Hunter Valley fault, for in such places the chances of error are tremendously increased and even if drawn the contours would have little or no practical value.

MAJOR STRUCTURAL FEATURES OF THE FIELD.

General statement.

The rocks of the coal-bearing portion of Wise and Scott counties, in general, lie in the bottom of a broad shallow trough or elongated basin, which has been the means of their preservation from erosion. This general trough, however, is notably modified in southern Wise and Scott counties by a broad, gently westward-rising anticline that has elevated the coal-bearing rocks in this region, with the consequent loss by erosion of the higher, more valuable coal beds. The rocks in that portion of the Wise and Scott counties field affected by this anticline are so notably barren of coal beds and so different from those in the main coal field that it is generally regarded as a distinct field called the Powell Mountain coal field. The line of demarcation between the Powell Mountain field and the important coal-producing field on the north agrees in general with the course of Guest River from its mouth at Clinch River northwest and west to Norton and from Norton with the course of Powell River and Pigeon Creek along the north face of Powell, Little Stone, and Stone mountains, in a westerly direction to the Lee County line. With a few minor exceptions, all the coal shipped from Wise County is taken from beds occurring in the structural trough north of Powell Mountain, indicating the present relative non-importance of the Powell Mountain field.

The southeastern limit of the Wise and Scott counties coal field is marked in part by a fault and in part by the normal upturning of the beds on the flank of a sharply folded syncline. In eastern Wise and Scott counties the coal field is abruptly cut off by a fault and in western Wise County and eastern Lee County the beds are upturned along Stone Mountain without any evidence of an extensive and profound fault. These major structural features that affect not only the rocks of Wise and Scott counties but extend into the adjacent counties, are described in detail. A serial diagram is given in Fig. 10 showing the development of the major folds and faults.

Powell Valley Anticline.

The great arch formed at the same time that the Middlesboro syncline was produced is called the Powell Valley anticline from the great valley that has been eroded in its crest. The axis of this fold enters Wise County from the southwest near the town of Big Stone Gap and then passes about 1 mile south of Little Stone Gap. It continues due east to Guest River where the flattening out of the anticline makes it difficult to exactly locate the axis. The axis of the fold decreases in elevation 3,000 feet from a point south of Little Stone Gap eastward to Guest River, a distance of $13\frac{1}{2}$ miles or at a rate of 227 feet per mile. A prolongation of the fold extends northeastward into Russell County from the vicinity of the mouth of Hurricane Creek of Guest River, and the name Powell Valley anticline is applied also to this fold in Russell County. A second and minor prolongation of the anticline branches from the main fold south of Coeburn and trends southeastward towards Carfax.

Like most folds in the Appalachian region, this anticline is unsymmetrical; the rocks on its northern side, forming Stone and Little Stone mountains, dip from 50 to 80 degrees to the north, whereas the rocks on its southern limb dip gently away from the axis and gradually merge into a shallow syncline on the south. The steep dips of the north limb become more gentle from Ramsey east, ranging at Tacoma from 15 to 25 degrees and at Coeburn 5 to 10 degrees. The minor syncline on the south is in large part lost by the crushing and folding back on themselves of the rocks which originally formed the southeastern limb of the syncline.

Middlesboro syncline.

The broad shallow trough that extends through northern Wise County in a northeast-southwest direction is called the Middlesboro syncline. This great trough has a width in the vicinity of Norton of about 14 miles and a length of about 140 miles, extending from the Breaks of Sandy to the southwestward far into Tennessee. It is a structural feature of great economic importance to Wise County as in it lie the thickest and purest coal beds of the Wise and Scott counties field, that elsewhere have been eroded away. It receives its name from Middlesboro, Kentucky, near Cumberland Gap, where the syncline is well developed.

In Wise County the Middlesboro syncline is unsymmetrical, the deepest part or the axis lying only a few miles southeast of Pine Mountain, and corresponding in a general way with the course of Pound River and the South

Fork of Pound River. On account of its unsymmetrical shape, the northwest side of the trough is considerably steeper than the southeast side, the rocks rising uniformly toward the high linear crest of Pine Mountain. The formation of the syncline was brought about by long continued and intense

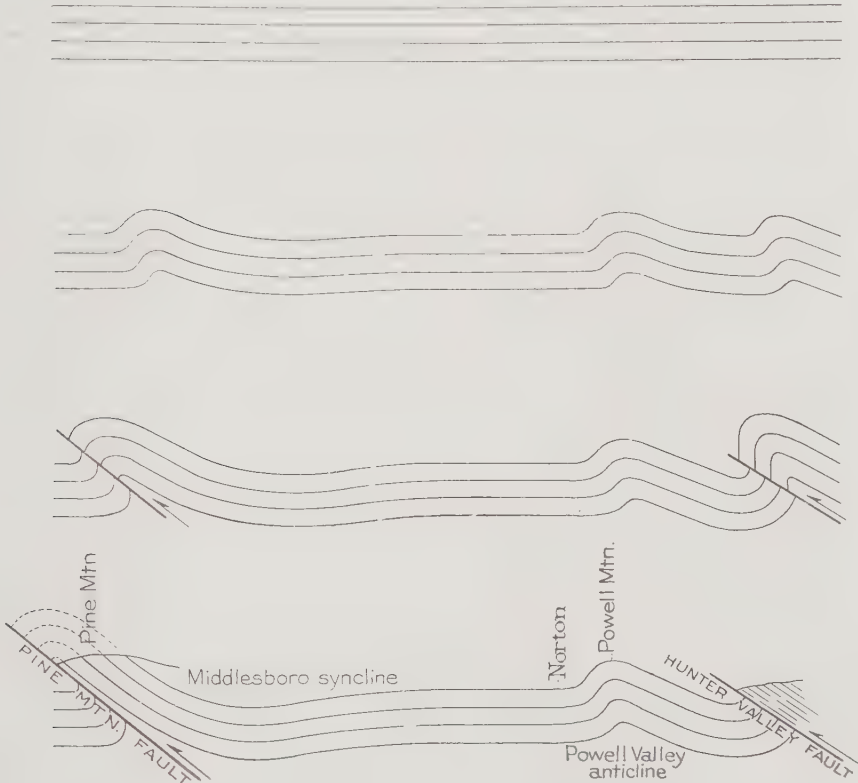


Fig. 4.—Serial diagram showing development of major folds and faults.

pressure from the southeast which bent the rocks into great folds similar to the folds produced in a pad of paper when pressed with great force from either side. The rocks on the southeast of the Middlesboro syncline were raised into a great arch known as the Powell Valley anticline and the rocks on the northwest into a similar arch which may be called the Pine Mountain anticline. Upon the continuation of the intense pressure as indicated by the arrow in Fig. 4 the arches broke and the southeast limbs of the anticline were thrust over and upon the northwest limbs. Since the folds were produced erosion has worn the rocks down until the relief is comparatively

slight and the position of the folds are indicated by the hard rocks of Stone and Pine mountains. Along the crest of Pine Mountain the southeast dip of the rocks ranges from 20 to 40 degrees and in the Middlesboro syncline the dips range from zero at the axis to about 10 degrees near the foot of Pine Mountain.

West of Norton the Middlesboro syncline is quite definite being bounded on the northwest by the Pine Mountain faulted anticline and on the southeast by the Powell Valley anticline, but east of Norton the syncline grows broader and broader as the Powell Valley anticline dies out until near the east line of Wise County it extends entirely across the coal field from Pine Mountain on the northwest to the overturned rocks forming the southeast rim of the syncline in the vicinity of St. Paul. In this expanded part the axis still holds its position near the base of Pine Mountain and from this line the rocks rise gently but irregularly with many slight subordinate folds or wrinkles to the southeast margin of the field. In the Middlesboro syncline generally there is little disturbance of the rocks in the middle of the trough, the massive formations underlying the trough seem to have been competent to transmit the thrust that was not used up in producing the great fold of the Powell Valley anticline. In Wise County, however, this great fold began to die down and the thrusts that in other places had been relieved by the production of the big fold here found expression in a number of minor folds or wrinkles that extend nearly across the syncline in a north-south direction. In other words the northwestward thrust here has been resolved into two components, one producing the diminishing extension of the main fold in nearly an east-west direction, and the other, the north-south wrinkles, here being considered. In these folds the western limbs of the anticlines are usually steeper than the eastern limbs and in places, such as in the vicinity of Wise and Glamorgan, the western limb approaches verticality and the eastern limb is nearly flat.

Gladeville Anticline.

The most pronounced of the minor folds is one that branches from the main Powell Valley anticline just east of Ramsey. This fold was named by Campbell¹ the Gladeville anticline for the town of Gladeville (now Wise) which is located nearly on its crest. The Gladeville anticline is the sharpest fold in the rocks of the coal basins north of Powell Mountain and is the only fold in this region bringing to the surface the massive sandstone

¹ Op. cit.

beds of the Lee formation. The anticline extends north as a protuberance on the flank of the great arch of the Powell Valley anticline. The up-folding of the Gladeville anticline has brought the thick conglomeratic "Bee Rock" of the Lee to the surface considerably north of its normal boundary at the north foot of Powell Mountain. This is well shown in the valley of Guest River, one-half mile east of Ramsey, where the river has been crowded far to the north by having slipped down the conical surface of the "Bee Rock."

The axis of the fold from $\frac{1}{2}$ mile east of Ramsey where it enters the rocks of the coal basins, extends slightly west of north, crossing the Norton-Wise pike $\frac{1}{2}$ mile west of Wise and thence due north through Glamorgan to Pound.

This fold where it branches off Powell Mountain is quite symmetrical, but further north it develops into a very unsymmetrical anticline with the steeper dips on the west limb of the fold and very slight dips on the east limb. In fact the wrinkle in many places develops into a sharp monoclinial fold with little or no descent east of the axis, but a sharp dip on the west side into the Dorchester syncline. In another respect this fold is very peculiar, for its crest is marked in two places by very marked local elongate domes which carry the crest several hundred feet higher than it is either to the north or the south. One of these local domes, occurring directly west of Wise, is very striking for it is capped by the massive Gladeville sandstones and so makes a pronounced elevation in the surface. The dips on the west side of this dome are so sharp that a small stream heading a little north of the dome and joining Guest River at Esserville has cut through the massive Gladeville sandstone destroying the western half of the dome, as a surface feature.

North of the dome just mentioned the Gladeville anticline takes mainly the form of a monoclinial fold which passes through the coal-mining town of Glamorgan and across the divide about $\frac{1}{2}$ mile to the north. On the north side of this divide another elongate dome has developed with dips of 20 to 50 degrees on either limb. This dome reaches its maximum development in Indian Gap, and north of that place dies down even more suddenly than it appeared at the other end. Here again the Gladeville sandstone is the principal rock of the dome, but in Indian Gap another and higher sandstone—the Addington member—forms the surface.

North of Indian Gap the Gladeville sandstone dips suddenly to the north at about the same rate as the surface slopes in the same direction and at the mouth of Tank Hollow it passes below creek level, but it is probable that

at no place is it more than 10 feet below the bed of Indian Creek. From Tank Hollow to Lick Branch the Gladeville is at, or just below, creek level and the fold is a sharp monocline, though dying down in magnitude gradually toward the north. Below Lick Branch the Gladeville sandstone has been cut into by Indian Creek and the top of this massive bed is from zero to 50 feet above creek level.

The most striking features of the Gladeville anticline are the domes already described and the wonderful straightness of the axis for a distance of at least 12 miles. The writer is at a loss to explain the meaning of the sharp domes on this fold. Why the forces should be localized at these places is a question that is apparently unanswerable, as the surface rocks are no different here from what they are at other places, and there seems to be no compensating constrictions in the adjacent syncline on the west. The extreme straightness of the fold is also peculiar. South of Indian Gap the fold has had only a slight effect on the surface features, but north of the gap it has apparently determined the course of Indian Creek, which at once attracts the attention, because of its straight course which is so different from the streams in adjacent territory.

Buck Knob Anticline.

A second pronounced anticline crosses the coal basin in a nearly north-south direction, the axis of the fold starting at the belt of upturned rocks at the mouth of Lick Branch of Powell River and running in slight curves north over the crest of Buck Knob and continuing across the forks of Pound River. This fold is called the Buck Knob anticline. The dips on the west side of the fold are steeper than those on the east side, and on the west side are considerably steeper on Black Creek than they are farther north on Upper Guest River or in the Pound River drainage basin. The form of the Buck Knob anticline is decidedly unsymmetrical, the greatest descent to the east or to the axis of Dorchester syncline being less than 500 feet, whereas the greatest descent to the west or to the axis of the Middlesboro syncline is more than 1,500 feet, considering only the rocks in Wise County. On the anticlinal axis north of Buck Knob the Imboden and Kelly coal beds are about 2,200 feet above the sea; on the Dorchester synclinal axis they are 2,000 feet, the eastward descent being 200 feet in 2 miles; on the Middlesboro axis west of Dewey the same beds are about 1,900 feet above sea level, giving a westward descent of 300 feet in about 2 miles. East and north of Dewey in the prolongation of the Buck Knob axis, the anticline flattens out rapidly.

Dorchester Syncline.

Between the Buck Knob anticline on the west and the Gladeville anticline on the east lies the Dorchester syncline, named for the town of Dorchester, through which the axis of the syncline passes. The syncline is a shallow trough with its axis running through Josephine in a general northerly direction to the south slope of Pine Mountain. It is unsymmetrical, the west side having gentle dips and the east side steeper dips, with very steep dips locally. At Glamorgan the westerly dip of the east limb is 10 degrees and $\frac{3}{4}$ miles north, at the intersection of the highway with the old tram-road it is 40 degrees. On the west side of Indian Creek, 5 miles above the mouth, the Clintwood coal and overlying Addington sandstone dip 10 degrees west. The synclinal axis crosses the Middlesboro synclinal axis $1\frac{1}{2}$ miles southwest of Pound, making a structural depression more than 250 feet deep. The rocks rise rapidly to the north out of this depression and all vestige of the syncline is lost at the base of Pine Mountain.

Pigeon Creek Fault.

The contact of the upturned rocks with the horizontal rocks along the north face of Stone, Little Stone and Powell Mountains, from Blackwood east, is apparently a very abrupt but unbroken fold, and from the vicinity of Blackwood west, a fault ranging in displacement from nothing to a maximum at Big Stone Gap of about 1,500 feet. The trace of the fault coincides with the lower course of Pigeon Creek and as the fault here has its greatest displacement, it is called the Pigeon Creek fault. (See fig. 5). Southwest from Big Stone Gap the fault gradually decreases in throw to the Lee County line where no fault could be detected. A fault at the same relative position as the Pigeon Creek break begins a short distance west of the Olinger Gap road in Lee County and continues beyond Pennington Gap. Although the faults are in line they do not join, and the one in Lee County has been called the North Fork fault.¹

The Pigeon Creek fault was first recognized by Campbell as stated on page 79, but he thought the fault was limited to the vicinity of Big Stone Gap and was of slight stratigraphic displacement. It is now known that the maximum stratigraphic displacement of this fault is about 1,500 feet, and hence it is no wonder that in the days of the early development of this field, the geologists, with no conception of a fault at the upper end of Big

¹ Giles, Albert W., The Geology and Coal Resources of the coal-bearing portions of Lee County, Virginia. Unpublished manuscript.

Stone Gap, should have arrived at a totally erroneous idea of the magnitude of the interval between the "Bee Rock" and the Imboden coal bed. The key to the whole situation is revealed, however, when one sees the Gladeville sandstone disappear below drainage level at Blackwood and reappear only on Laurel Fork of Pigeon Creek. He then begins to realize that the break is of considerable magnitude and is a most important feature of the geology of the coal field.

The presence of the Pigeon Creek fault has been established beyond question, but the exact method of its formation may be regarded as still a matter of doubt. Every geologist who has worked in this coal field has been impressed with the great amount of crumpling, crushing, and slipping on bedding planes that has taken place in the disturbed belt at the north-west foot of Stone Mountain, but in such a place it is difficult to recognize faults. The writer doubtless would not have been able to do so at the present time were it not for the logs of diamond drill holes and other exact data that are available.

The key to the explanation of the method of faulting was found in a comparatively recent deep cut on the Interstate Railroad in the vicinity of Blackwood. So far as known there is no fault of any considerable amount of displacement at Blackwood, the fault evidently developing southwestward from this place.

It is plainly apparent that in the upturning of the beds on the right the bed of sandstone lying horizontally on the left has served as a buttress against which the other beds were thrust and crushed. It also shows that the part of the sandstone bed that was partly upturned was badly crushed, although probably more resistant than the adjacent shale and coal beds, and that instead of bending in response to the thrust it was crushed and offset to the left. The writer believes that the buttress effect of the horizontal beds in the Middlesboro syncline is the key to the interpretation of this fault. In accordance with this idea he has prepared Fig. 5 in an attempt to show how the fault may have been produced, but as no one diagram can correctly represent the conditions of faulting, slipping on bedding planes, and mashing, Fig. 5 must be regarded only as suggesting rather than representing, the actual origination of the fault.

In Fig. 5, A B C represents an assumed position of the top of the Lee formation before a fault had developed. D E F represents the Gladeville sandstone, and the heavy line above, the Imboden coal bed. In the further development of the great anticline on the right—(Powell Valley anticline)—the Lee formation was bent abruptly at B and in the relatively soft rocks

of the Norton and Wise formations overlying it, there was a great amount of crumpling, crushing, faulting, and slipping on the bedding planes to accommodate the formations to the reduced arc of the curve. In this crushing the nearly flat-lying beds in the bottom of the Middlesboro syncline served as a buttress against which the crushing and crumpling took place. Thus the Gladeville sandstone (D fig. 5) being the most resistant of the forma-

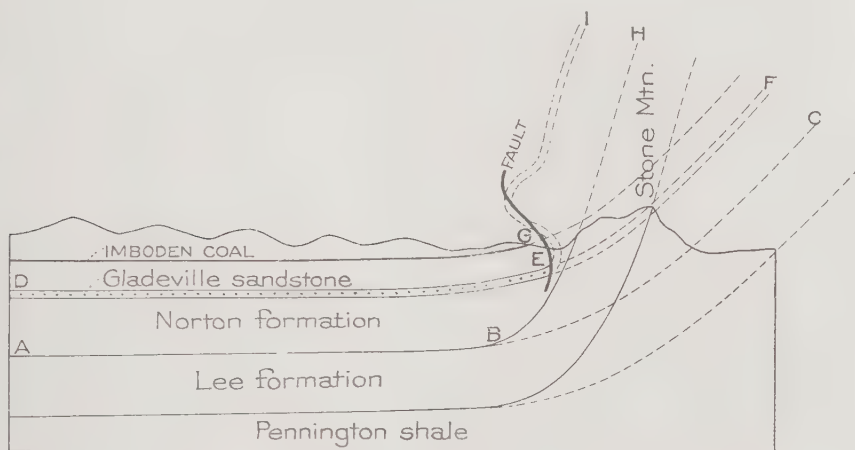


Fig. 5.—Structure section across Pigeon Creek fault.

tions above the Lee received the brunt of the thrust. As it was not closely confined by a great mass of relatively weak material, it early broke at E and then as the Lee formation was crowded farther and farther toward the northwest the beds of the Norton formation were almost squeezed out between the advancing resistant plate of the “Bee Rock” and the resistant and practically immovable horizontal plate of the Gladeville sandstone. The effect was the same as though the Gladeville sandstone had been under-thrust against the flank of the rising arch and a “crush fault”¹ was produced.

That part of the Gladeville sandstone which lay on the flank of the arch had in the meantime to adjust itself to a shorter arc and it is assumed that this adjustment was made by a minor sigmoid curve as shown in Fig. 5, but as the Gladeville is a hard, brittle stratum in the midst of much softer rocks, it is probable that instead of bending in a regular curve it was broken into blocks which adjusted themselves roughly to the form indicated in

¹ A term suggested by M. R. Campbell.

Fig. 5. The net result of the adjustment of the various beds is a crush fault zone about as indicated in Fig. 5, the fault dying out at each extremity in movement along bedding planes.

The amount of stratigraphic displacement is determined by the relation of the Gladeville sandstone to the "Bee Rock" of the Lee formation at the point E. As indicated in the diagram the Norton formation has been practically crushed out at this point and as that formation has a thickness of about 1,425 feet, the stratigraphic displacement is about the same amount, but being different at different places along the trace of the fault.

The explanation of the origin of this fault seems to be more nearly in accord with the observed facts than any yet suggested, but it is put forward by the writer in a tentative way only, with the hope that geologists having experience with similar structures may analyze it carefully and if it appears to them unsatisfactory, to suggest other modes of origin or modifications of this method. This fault is of the overthrust variety as the older rocks on the southeast side of the break have been thrust against and even upon the younger rocks on the northwest side of the break. Although this fault has some of the characteristics of the great overthrust faults for which the **Appalachian** region is noted, it apparently has not developed from an overturned fold as is generally the case with faults of this kind.

Hunter Valley fault.

When the coal-bearing rocks were formed they extended much farther to the southeast than they do today, but the parts east of the present coal field were lifted so high by the forces that produced the great folds and faults that they have been eroded and have left little or no trace of their former extent in this direction. As shown in Fig. 4 the present coal field was originally bounded on the southeast by a great anticline, which under the continued pressure from the southeast, finally broke and the rocks on the southeast side of the break were shoved forward and upward a great distance, probably many miles, until the limestones of Clinch Valley now rest on top of the coal-bearing rocks. The rocks forming the syncline to the northwest of the fault were so greatly thrust from the southeast that the southeastern limb of the fold was overturned until now the Lee formation back of St. Paul is completely overturned and it is little wonder that Lesley thought that it was the same bed as the Gladeville sandstone.

The course of the profound break, cutting off sharply the coal-bearing rocks of Wise and Scott counties at the south foot of Powell Mountain, con-

forms in general with Hunter Valley, from whence it receives its name. The fault zone is one of the most extensive in the Appalachian province, having a length of 370 miles and a stratigraphic displacement in eastern Wise County of 15,000 feet. The fault zone extends from near Rome, Georgia, to New River, Virginia, and is the southeastern limit of all known coal measures of Pennsylvania age.

The overturned rocks adjoining and lying northwest of the fault zone generally involve hard beds and form ridges which mark the margin of the coal field throughout Scott and Wise counties. Commonly the coal beds in these upturned rocks are so badly disturbed and crushed that they can not be profitably mined, but in places mines have been opened and considerable coal produced.

At Burtons Ford (Russell County) coal is now being mined from an overturned coal bed beneath an over-burden of Cambrian limestone. Such overturning is evidence of the great thrust from the southeast that at one time must have developed in this field. The magnitude of the Hunter Valley fault decreases towards the southwest and Mississippian rocks are exposed between the Cambrian and Pennsylvanian beds west of St. Paul. West of Dry Creek of Clinch River, Devonian beds are exposed continuously as far as Stony Creek; here the Devonian rocks are bounded by faults on the north and south sides of their outcrop, and a transverse break cuts off their westward extension. Southwest of Stony Creek the Hunter Valley fault is a single clean-cut fracture bringing the massive Cambrian limestone in contact with the Pennington shale. West of Cove Creek a small block of Big Stone Gap shale is faulted up between the limestone and Pennington shale. The main fault passes southwest through Horton Summit or Sunbright into the non-coal-bearing portion of Virginia. The Newman formation which is widely exposed north of the fault at Sunbright, is the lowest formation shown on the map north of Hunter Valley fault. The fault is represented throughout its entire extent in this field.

Pine Mountain fault.

The great anticlinal fold which originally developed along the present Pine Mountain, as shown in Fig. 4, was affected by the thrust from the southeast transmitted through the flat-lying rocks of the Middlesboro syncline. The first effect was to push the fold over toward the northwest and then when the rocks could no longer withstand the pressure to break along the overturned limb. This breaking relieved the rocks of the intense

stress and the whole Middlesboro syncline was doubtless thrust far over the nearly horizontal coal-bearing rocks of Kentucky.¹ The fold and the fault are shown diagrammatically in Fig. 4.

The Pine Mountain fault took place in a straight line paralleling and lying about $\frac{1}{2}$ mile northwest of the crest of Pine Mountain. As the State line follows the crest of the mountain the fault does not at any point enter Wise County. The far-reaching effects of this break, however, in the rocks of Wise County connects it intimately with the geology of this field and hence the fault will be described somewhat in detail.

According to recent work by Butts and Keith the fault is compound in places, breaks having occurred on two or more planes that are close together everywhere and joined in some localities. The breaks for purposes of description may be considered as having occurred at different times. By the earlier break the Lee conglomerate, extending from Jewell, Kentucky, southwestward along the mountain front, was thrust into contact with rocks about 2,400 feet higher than the top of the Lee. Later another break occurred along which the displacement varies; west of Pound Gap road the Mississippian is in contact with the wedge brought up by the earlier fault; north of Indian Grove Gap the fault brings Devonian black shale in contact with the Lee formation; and farther to the northeast the movement was so great that the upper 800 feet or so of the black shale has been thrust over the earlier fault plane and is in contact with Pennsylvanian rocks, the total displacement here being about 4,900 feet.

The two great breaks—the Pine Mountain and Hunter Valley faults,—are respectively, the northwest and the southeast faults bounding two sides of the “Cumberland block” as described by Wentworth.² The formation of these folds and faults has resulted in the lifting and loss of great areas of coal-bearing rocks. How far the coal fields originally extended southeast of the Hunter Valley fault is not known, and there is no means of determining the vast amount of coal lost by erosion following the thrusting up of the coal-bearing rocks over the plane of the Pine Mountain fault. No geological phenomena have so profoundly modified the coal fields of southwest Virginia as the thrusts which produced these great folds and faults.

¹For a more extended consideration of the mechanics of faulting in this region the reader is referred to a chapter on the “Russell Fork fault,” by Chester K. Wentworth, *Geology and coal resources of Dickenson County, Virginia, Va. Geol. Survey Bull. XXI*, pp. 53-67, 1921. *Idem*, *Jour. of Geol.*, vol. 29, No. 4, pp. 351-9, 1921.

²Loc. cit.

ECONOMIC GEOLOGY

GENERAL DESCRIPTION OF COAL BEDS.

INTRODUCTION.

The total thickness of coal-bearing formations in Wise and Scott counties ranges from 4,800 to 5,570 feet, every portion of which is exposed in either one or the other or both of the counties. At least 26 coal beds, 30 inches or more thick, consisting of high-grade bituminous coal, occur in these formations in sufficient acreage to justify mining. Of the 26 beds 23 outcrop in Wise County and 3 in Scott County. Thinner coal beds occur in scattered localities in the field and there are at least five beds in addition to the 26 major coals that are locally thick enough to mine to advantage at the present time. In general, however, these thinner beds can not be profitably mined until the thicker beds have been exhausted and the demand for coal is greatly increased. The total tonnage of coal now found in beds that are workable under present conditions and in thinner beds that will be minable in the future, is enormous as indicated in the tables on later pages of this report.

The physical features of the coal beds of Wise and Scott counties, as of nearly all the beds in southwest Virginia, are so different in different districts that no bed can be identified throughout its entire extent, or even in small areas, by means of these features alone. The beds vary in thickness, character and size of partings, floor and roof, and to a certain extent in character and quality of coal. One marked exception to this general statement is found in the Upper Banner bed in Wise County which has a persistent thin sandstone parting that occurs throughout many square miles of the coal field. In prospecting the bed was largely identified by means of this parting. To a lesser extent the Imboden coal bed of western Wise County can often be distinguished from higher beds by the presence of zones of crushed or "curly" coal.

In addition to making use of the physical features of the coal, the outcrop of coal beds can often be traced by seeps or springs of water at the surface where the natural outcrop of the bed is hidden by surface soil; or by tracing adjacent distinctive strata, such as an overlying or underlying prominent sandstone. The thickness and character of the bed can then be fully determined by a carefully dug pit into the fresh coal. Drill holes can be put down in the valleys to explore the beds that do not outcrop in the ridges.

The workable coal beds of Wise County are prospected by surface pits over fully 80 per cent of the county, disclosing invaluable information for anyone now seeking, or who will seek in the future, to exploit these beds. Through the courtesy of the prospecting agencies, practically all of this information was available and is incorporated in the following divisions of this report.

The impurities most generally present in coal beds are shale, hard clay, bone, "rash," and sandstone. "Bone" is a term that in the field was found to have a variety of local uses. As used in this report it means a layer of hard impure coal which in places grades uniformly into the adjacent soft clear coal and in other places is sharply separated from it. Bone is due to the presence of a considerable number of well distributed clay particles. "Rash" is an intimate admixture of coal and shale, formed in most cases by a differential movement of adjoining coal and shale beds, with a consequent crushing, "flaking", and mixing of coal and shale. The "flakes" of coal and shale in many places show slickensided surfaces. "Laminated" coal is composed of very thin alternating layers of shale or bone and coal, or of thin alternating layers of different quality coal, such as hard and soft or bright and dull coal.

Partings range in thickness from a fraction of an inch to several feet. Where partings exceed two feet it is seldom that more than one bench of the bed is recovered and the coal bed is said to be "split". A typical example of splitting of a coal bed occurs at Glamorgan. The floor of most mines and prospect drifts consists of a hard gray sandy clay, and the roof, in the majority of cases, is a firm shale or sandstone. In many instances a thin layer of shale occurs between the top of the coal bed and the solid roof, called "draw slate." This must either be removed or timbered in place in mining the coal bed beneath. Failure on the part of the miner to detect the presence of "draw slate" may result in serious accidents from falling roof. The character of a mine roof is rarely constant, even throughout small areas, and hence it is impractical to predict the type of roof likely to be encountered in new operations.

The minable coal beds of Wise County now exposed at the surface range from younger to older in a west to east direction. Thus the valuable Pardee bed on Roaring Fork is more than 3,000 feet stratigraphically above the Jawbone bed on Russell Creek, whereas the Norton and Dorchester coal beds of central Wise County lie nearly midway between the two beds at the extremes of the geologic column of the Norton and Wise formations. The occurrence of the successively older coal beds from west to east is brought about by the general northwesterly dip prevalent throughout much of Wise

County. The tendency of the lower beds to thin and deteriorate toward the west and northwest is a notable characteristic of the Wise County field. The Jawbone, Upper Banner, Norton and Dorchester are among the best examples of beds thinning towards the west.

Coal beds in the Norton formation.

TILLER COAL BED.

The lowest coal bed of much commercial importance in the Norton formation is the Tiller bed, which lies about 200 to 300 feet above the top of the Lee formation. The bed outcrops in workable thickness only on Russell Creek, on the Left Fork of Lick Creek and on Bull Run in eastern Wise County. The bed lies beneath the Jawbone, the interval ranging from a few inches to over 100 feet, with sandstone usually forming the intervening material.

The Tiller bed makes its best showing on Russell Creek and the Left Fork of Lick Creek, where it unites with the Jawbone to form a 9-foot bed. The two coal beds here go by the name Jawbone. On Bull Run, a bed of coal that is questionably referred to the Tiller is a bed of clear coal 5 feet thick. As the Tiller coal bed is so intimately associated with the Jawbone and so few openings have been seen on the Tiller bed, where it is separated from the Jawbone, the outcrop of the lower bed is not indicated on the geologic map.

The name Tiller was first applied by Stone¹ to the thick coal bed on Upper Indian Creek of Buchanan County. The upper part of this bed is now known to be the equivalent of the Jawbone, and the name Tiller is therefore restricted exclusively to the lower bench or bed. Hinds² suggests the correlation of the Tiller bed with the Lower Iaeger of the West Virginia Geological Survey.

JAWBONE COAL BED.

The coal bed overlying the sandstone above the Tiller bed is persistent throughout all eastern Wise County and is named the Jawbone bed, from

¹Stone, R. W., Coal Resources of the Russell Fork basin in Kentucky and Virginia: U. S. Geol. Survey Bull. 348, 1908, p. 92.

²Hinds, Henry, Geology and coal resources of Buchanan County, Va.; Virginia Geol. Survey Bull. XVII, 1918, p. 64.

Jawbone Hollow, a branch of Bull Run (see fig. 6). The interval between the Jawbone and the Raven bed, above it, is 175 to 200 feet, and is fairly constant.

The Jawbone bed ranges in thickness from 4 to 10 feet. Wherever the Tiller unites with the Jawbone to form a 10-foot bed, the resulting double bed will be called Jawbone for simplicity of nomenclature and the impracticability of separating the beds. Strictly speaking, therefore, it may be said the Jawbone proper, as shown by sections measured on Bull Run, where the Tiller is undoubtedly absent, ranges only from 4 to 6 feet. At Virginia City on Russell Creek the Jawbone bed ranges from 4½ to 5 feet thick. It is exposed in the upturned rocks along the south side of the field from a little east of Virginia City to the Russell County line. As exposed in the Ac Gose mine on Left Fork of Lick Creek the bed shows 9 feet of clear coal in one section, and a small nearly middle parting in another section. If the small parting near the middle of the bed indicates the line of separation between the Jawbone and Tiller beds, the Jawbone proper is about 4 feet thick at this locality. West of Craborchard Branch of Guest River the bed is thin and so parted as to be worthless. The bed south of Coeburn and west of Craborchard Branch outcrops practically at river (Guest River) level, and is of little value.

Many samples of the Jawbone were collected for analysis and the results are given in the table of coal analyses, all of which show an ash content from 15 to 19 per cent. This ash content is due to the presence of numerous bony streaks in the bed.

The Jawbone bed has been traced by its outcrop into Dickenson, Russell, Tazewell, and Buchanan counties, where it is found to be a persistent bed and usually workable. It is correlated by Harnsberger with the Iaeger bed of the West Virginia Geological Survey.

RAVEN COAL BED.

The Raven coal bed is about 475 feet above the top of the Lee formation and from 175 to 200 feet above the Jawbone coal bed (see fig. 7). The bed was first called "Garden Hole" from exposures of the coal bed at the Garden Hole on Russell Fork. In the early years of mining in Wise County the Raven bed at Tacoma was correlated with the Imboden coal bed on Callahan Creek. The correlation was quickly disproved, but the term "so-called Imboden" still remains and is often applied to the Raven in that section of the field. The name Raven was given to the bed in Tazewell County, where it has been mined for many years at Red Ash, near the town

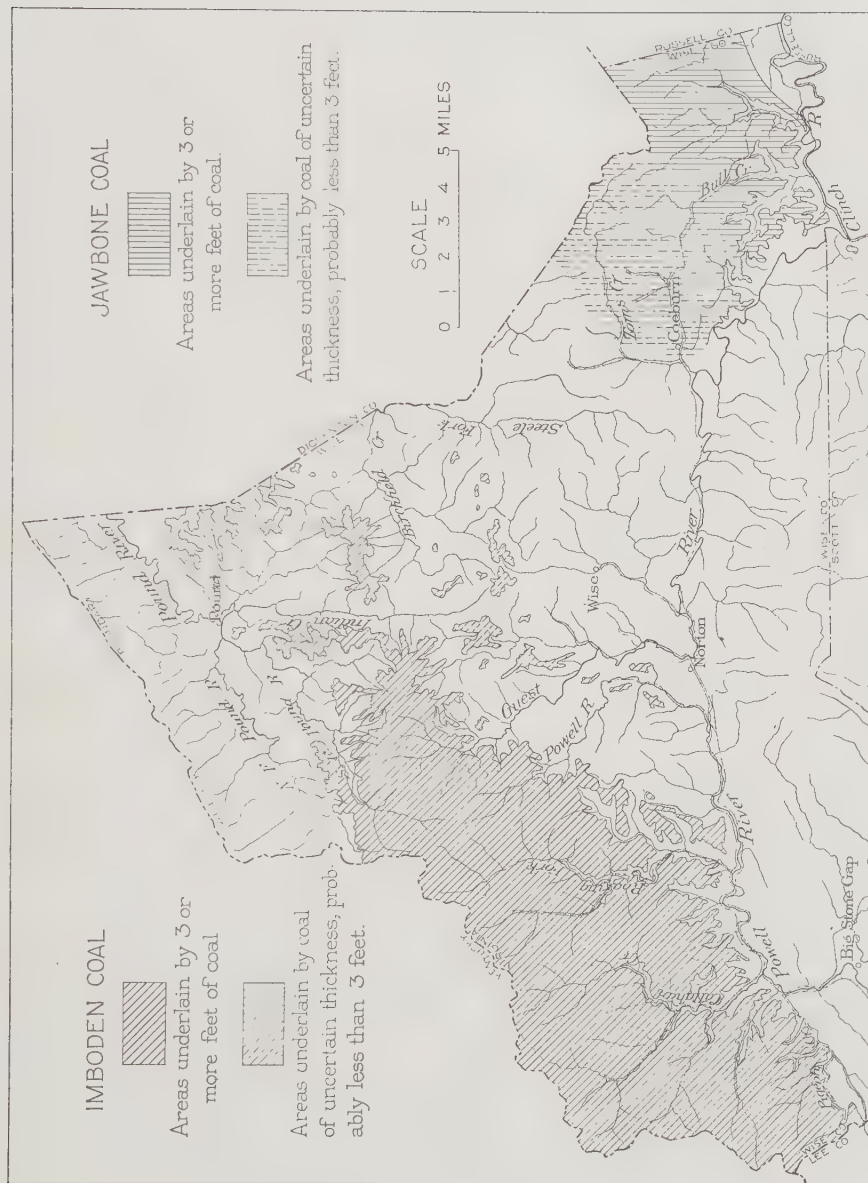


Fig. 6.—Sketch map of Wise County showing areas in which the Jawbone and Imboden coal beds contain 3 feet or more of minable coal.

of Raven. This bed is the same as the Lower Douglas coal bed of the West Virginia Geological Survey.

The Raven coal bed has an average section of $3\frac{1}{2}$ feet of coal, with 3 inches of parting on Russell Creek. The bed in the extreme eastern part of Wise County is shaly in places, to the extent of not being minable, hence it is of little present commercial value. The Twin City mine near St. Paul is in the Raven bed which shows $3\frac{1}{2}$ feet of coal, as the average section. The bed is worked to a small extent on Bull Run, where it contains not to exceed $2\frac{1}{2}$ feet of coal. From Tacoma to Coeburn it is variable in thickness and character. At Tacoma the coal is 3 feet thick, split by 1 foot of clay and "rash." The coal is not uniform within the bed, showing zones of hard and soft coal, although the quality of the coal does not seem to be altered by zonal induration. Towards Coeburn the bed increases to more than 4 feet in thickness. South and southeast of Coeburn the bed is impure and of doubtful value. A massive, thin-bedded sandstone that outcrops 10 to 20 feet below the bed is found throughout much of eastern Wise County and has been of much assistance in tracing the outcrop of the coal bed.

KENNEDY COAL BED.

No coal beds of workable thickness are found in the interval between the Raven bed and the Kennedy bed. The Kennedy coal bed, or, as sometimes locally called, "Widow Kennedy," is 150 to 170 feet above the Raven in the vicinity of Tacoma and from 200 to 280 feet above the Raven on Russell Creek and Left Fork (see fig. 8). The interval between them on Little Toms Creek reaches the minimum thickness of 150 feet. A thick sandstone, sparingly conglomeratic, called the McClure sandstone, one of the few prominent sandstones in the lower part of the Norton formation, lies beneath the Kennedy coal bed. The Kennedy coal bed is the same as the Douglas bed of the West Virginia Geological Survey.

Throughout much of its extent in eastern Wise County (see fig. 8) the Kennedy bed consists of crushed, laminated coal; a characteristic feature of the bed in the Virginia coal-bearing counties to the Northeast. It has a long circuitous outcrop in eastern Wise County occurring low in the ridges and running from the noses of the spurs to the heads of the many long valleys. However, whereas the bed is readily accessible, it is not of sufficient thickness or excellence to enable it to compete with the higher and better coal beds, with the result that the bed is now being mined at only a few places. The average thickness of the bed at Tacoma is $2\frac{1}{2}$ feet of clear coal. Near Coeburn, in the mine of the Standard Coal Company, the bed

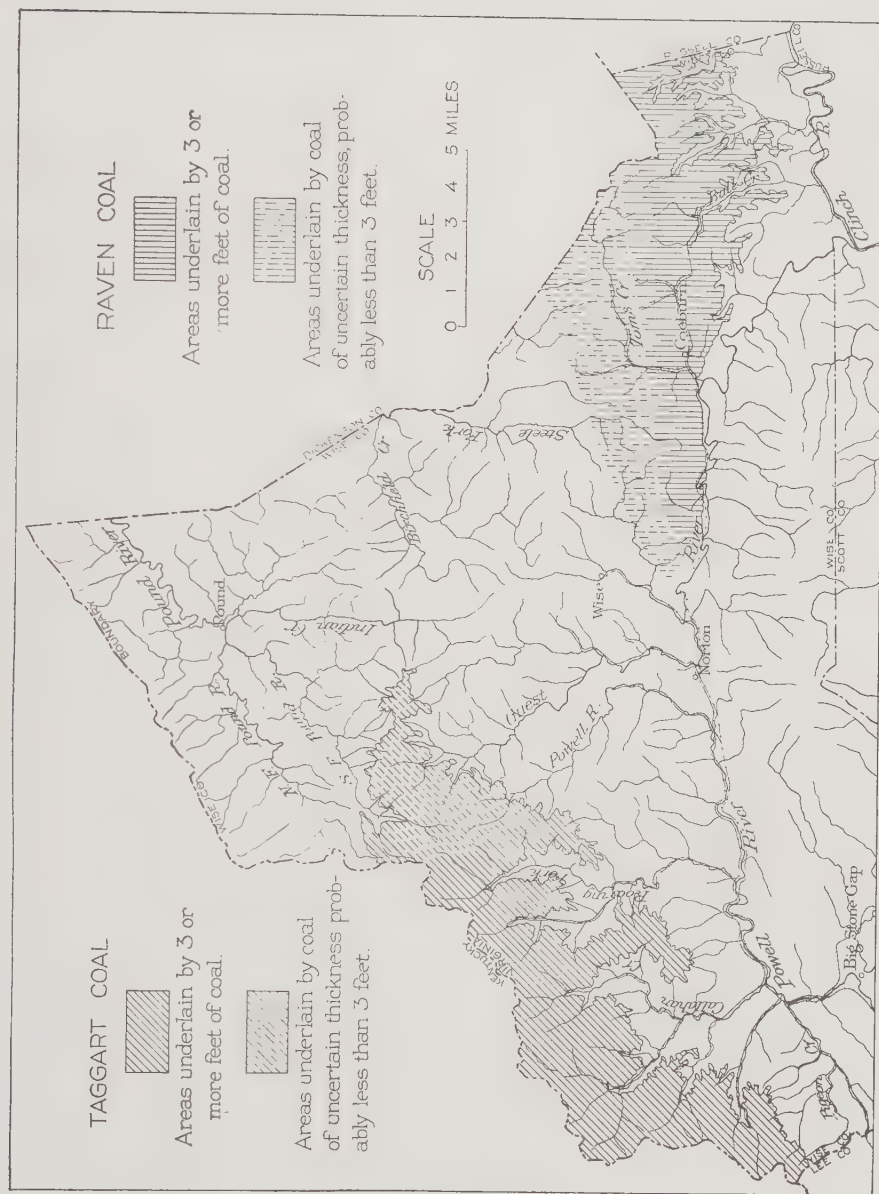


Fig. 7.—Sketch map of Wise County showing areas in which the Raven and Taggart coal beds contain 3 feet or more of minable coal.

is 44 inches thick and without a parting. It is uniformly overlain in this vicinity and towards Tacoma by a 15-foot bed of sandstone. East of Coeburn the Kennedy ranges from 2 to 4 feet thick, usually consisting of laminated or "rashy" coal. The bed in workable thickness is reported to have been recently opened on Meade Creek, a branch of Russell Creek. It is undoubtedly workable throughout the larger part of eastern Wise County, but it can not rank in importance with the Upper Banner bed.

LOWER BANNER COAL BED.

The Lower Banner coal bed is one of the most uniform beds in eastern Wise County, ranging from 30 to 45 inches in thickness, without partings (see fig. 9). In the neighborhood of Tacoma it is 180 feet and on Russell Creek 200 to 225 feet above the Kennedy. At Banner, on Little Toms Creek, the type locality of the two Banner coals, the lower bed is only 100 feet above the Kennedy bed. The Lower Banner bed is supposed to be the same as the Silbert bed of the West Virginia Geological Survey.

There are several mines operating in the Kennedy bed near Tacoma, where it is 40 to 50 inches thick and without partings. The bed is featured by zones of hard and soft coal, of good bituminous rank. In a mine at Coeburn the Lower Banner shows 52 inches of coal with 2 inches of parting. On Little Toms Creek the bed is thinner and more parted. At the Robert Fleming mine N. 1 at Banner the bed is 2½ feet thick. The Lower Banner bed is thicker at Pine on Bull Run, showing 5 feet of coal. To the east, however, it thins and is but little more than 2 feet thick in the Russell Creek drainage basin. The areas in Wise County underlain by workable Lower Banner coal are graphically shown in Fig. 9.

UPPER BANNER COAL BED.

One of the best known and most important coal beds in southwest Virginia is the Upper Banner bed (see fig. 10). It is mined extensively at Toms Creek, Banner and Pine in Wise County, and at Dante and Wilder in Russell County. The bed is 1,050 feet above the top of the Lee formation 400 to 425 feet below the base of the Gladeville sandstone, and, in general, is 150 feet above the Lower Banner coal bed. Locally, a bed of coarse-grained sandstone outcrops about 20 feet above the bed, but in Sandy Ridge and its spurs a massive, ledge-making sandstone lies 160 feet above the coal bed.

The Upper Banner coal bed makes its best showing in Sandy Ridge. West from Tacoma the bed rapidly splits into thin and worthless benches.

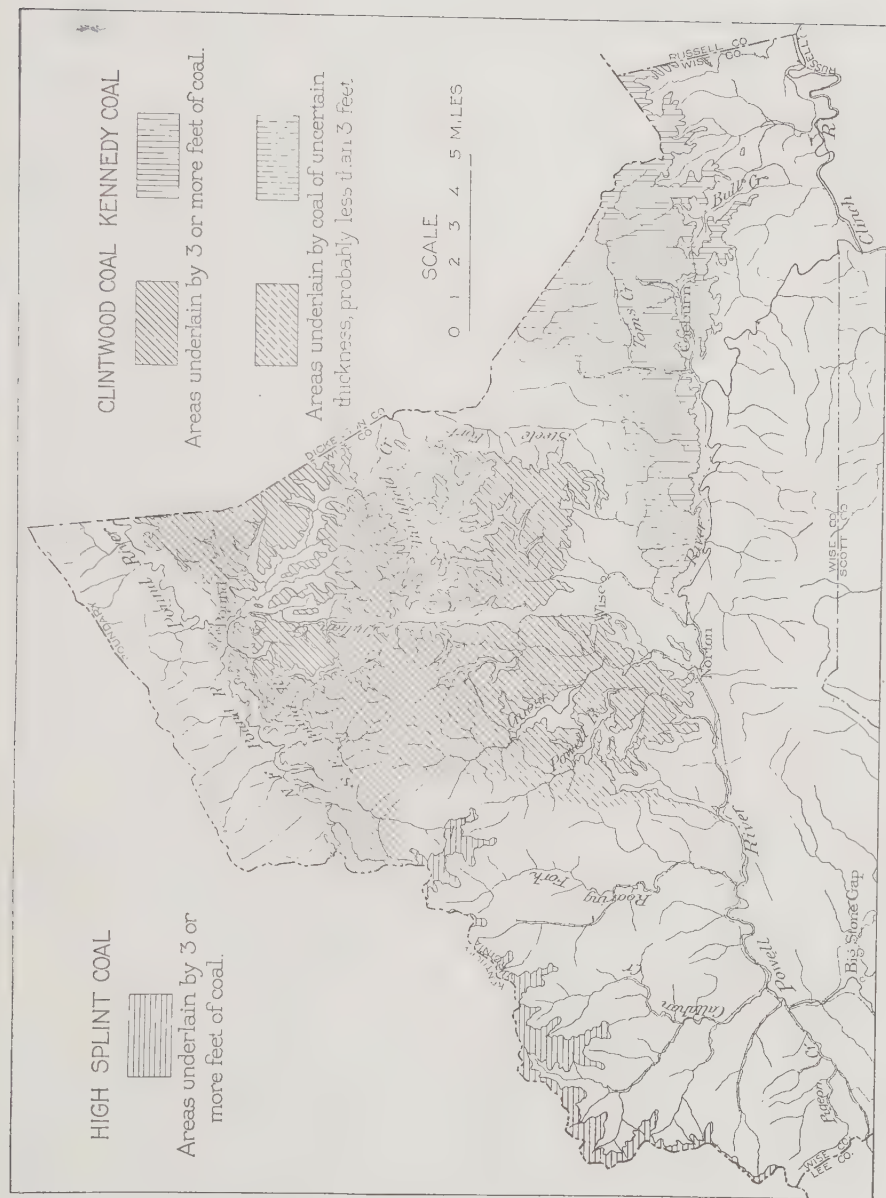


Fig. 8.—Sketch map of Wise County showing areas in which the Kennedy, Clintwood and High Splint coal beds contain 3 feet or more of minable coal.

East of Tacoma, throughout the Toms and Little Toms creeks basin, the Cranesnest River basin, and the head of the Bull Run basin, the bed ranges up to and in places more than 8 feet in thickness, with an average of 6 inches of partings. Its average thickness is about 6 feet. The bed is thickest in Sandy Ridge north of Toms Creek postoffice, or 2 miles north of Coeburn. In this locality it averages 7 feet in thickness. In the ridge dividing Steele and Trace forks from Guest River drainage the bed is considerably thinner, ranging up to 4½ feet thick. Throughout much of its extent the Upper Banner is parted usually near the middle by a characteristic bed of sandstone 1 to 2 inches thick. At some localities it is divided by two or more partings, usually of the same type of hard, carbonaceous, sandstone.

The largest economic development of the Upper Banner coal is taking place on Toms Creek, where the Virginia Coal and Iron Co. has several large mines. The Clinchfield Coal Corporation, which operates the large plants at Dante and Wilder, also has a mine opening on Guest River drainage, that serves as an outlet for Upper Banner coal mined by this company on Hurricane Fork and Caney Creek in Dickenson County. The coal is an excellent coking coal of high heating value and a large percentage of the coal mined at Toms Creek is coked at that town.

Many samples of the Upper Banner were collected in eastern Wise County mines for chemical analysis.

SPLASH DAM COAL BED.

A coal bed lying 70 to 90 feet above the Upper Banner bed is well developed in southwestern Dickenson County and is called the Splash Dam coal bed. It is of workable thickness in Russell County, but was seen only at a few localities as a thin bloom or a bed of carbonaceous shale in eastern Wise County.

HAGY COAL BED.

The Hagy coal bed is very poorly developed in Wise County and is not a workable bed. The Hagy coal bed lies approximately 160 feet above the Upper Banner bed and beneath a massive sandstone. It is named from exposures at the type locality in the Hagy mine on Trace Fork of Prater Creek and near Hagy School at Leemaster, in Dickenson County. The bed is exposed 1 mile north of Banner showing 2 feet, 8 inches of coal, but nowhere else was it found to be over 1½ feet in thickness.

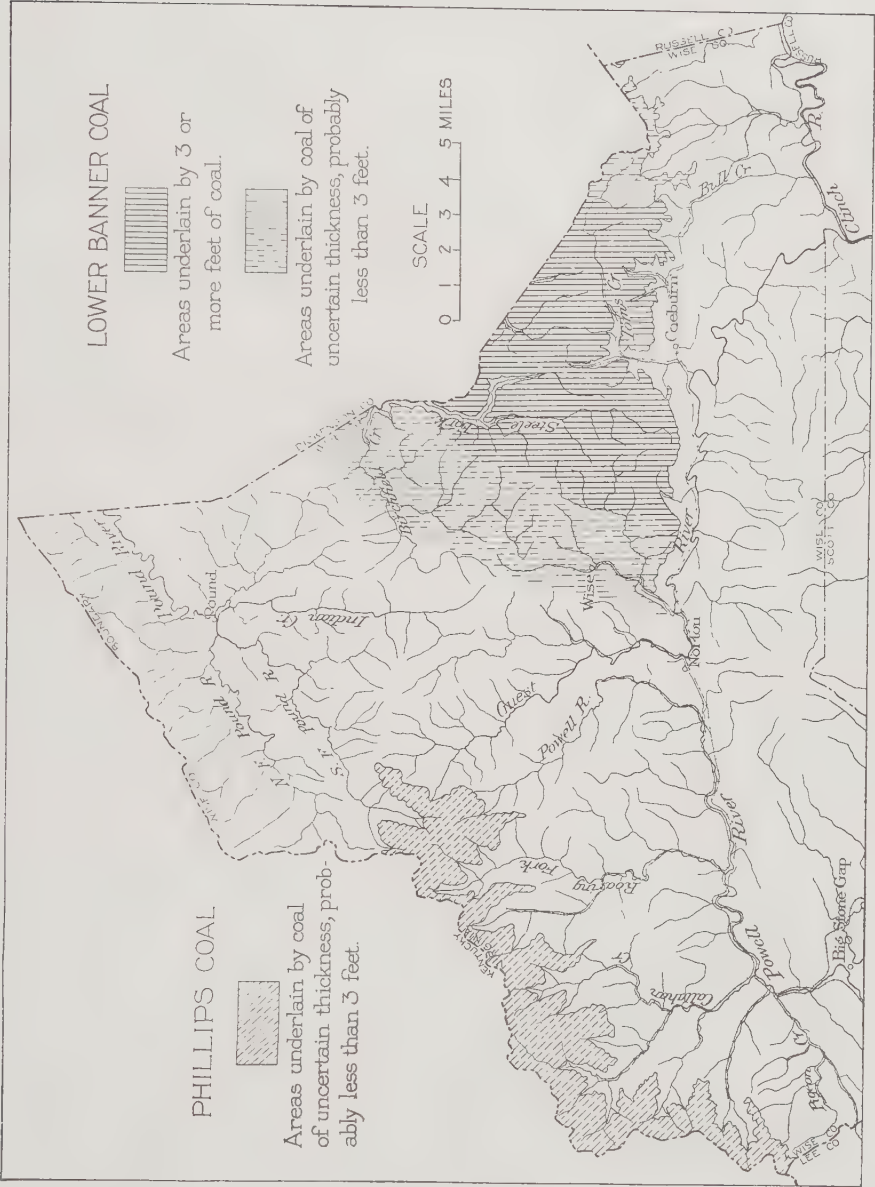


Fig. 9.—Sketch map of Wise County showing areas in which the Lower Banner and Phillips coal beds contain 3 feet or more of minable coal.

NORTON COAL BED.

The Norton coal bed is at or near the top of the Norton formation, cropping out with great regularity directly beneath the Gladeville sandstone (see fig. 11), although shale and clay beds in many places separate the coal and sandstone by an interval ranging up to 10 feet on the average, and as high as 40 feet at a few isolated localities. The bed was originally called the "Middle Norton" bed in the vicinity of Norton and Dorchester, and later the "Yellow Creek" bed near Wise. The former name was for a small settlement midway between Norton and Dorchester, near which the bed was first opened, and the latter name for Yellow Creek on which the bed was opened many years later. As the correlation of the "Middle Norton" with the "Yellow Creek" is established in this report, the latter name is dropped, and as the village of Middle Norton is now incorporated in the town of Norton, the modifying term "middle" is also dropped.

The Norton coal bed is best developed in the Upper Guest River basin in central Wise County, where it is thickest, ranging from $2\frac{1}{2}$ to 5 feet of usually clear coal. On Bear Creek drainage the bed thins to an average of 3 to 4 feet of coal with partings up to 1 foot in thickness. From the central portion of the county where the bed is of workable thickness, the Norton thins, in every direction, to a non-workable or questionably workable coal bed. In the Pound River drainage basin the bed is poorly exposed but nowhere shows a minable thickness. On upper Powell River the Norton bed is also little exposed but drilling shows it to range from 2 feet to 3 feet, 8 inches, in thickness. East of upper Guest River the Norton coal bed is workable to Tacoma, but from that place eastward the bed thins and is not of minable thickness.

The Norton coal is mined by the Norton Coal Co., the Hawthorne Coal Co., the Yellow Creek Co., the Gladeville Co., and many other smaller operators. It is among the large producing coal beds of Wise County. The Norton is a good coking coal, and a large percentage of the production from this bed is coked at the mines.

Coal beds in the Wise formation.

DORCHESTER COAL BED.

A coal bed of considerable commercial importance lies immediately above the Gladeville sandstone (see fig. 12). It was first described by Butts¹ and named by him the "Glamorgan" coal bed because Glamorgan

¹ Butts, Chas., The coal resources and general geology of the Pound quadrangle of Virginia and Kentucky, U. S. Geol. Survey Bull. 541, 1914, p. 174.

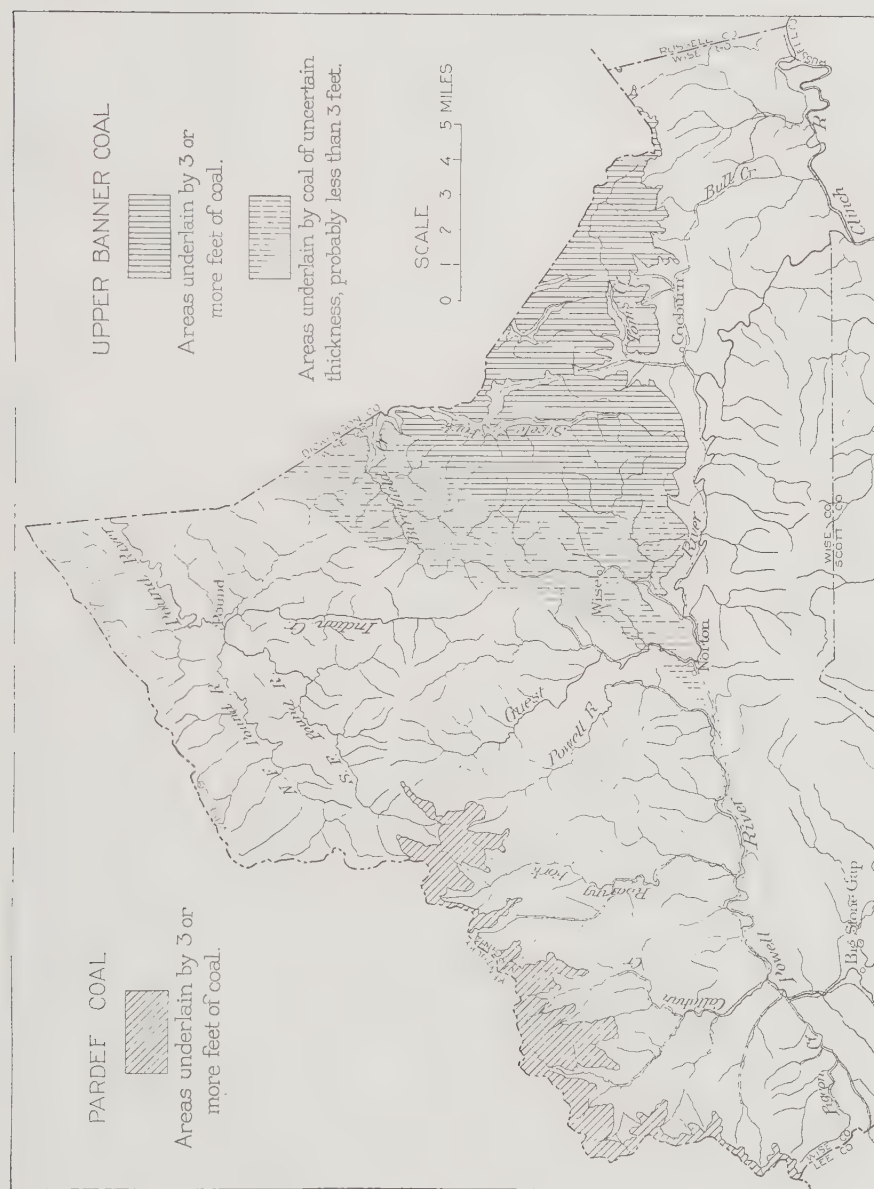


Fig. 10.—Sketch map of Wise County showing areas in which the Upper Banner and Pardee coal beds contain 3 feet or more of minable coal.

was the largest mine operating in this bed in the territory he was describing. The present work has shown that the coal bed immediately above the Gladeville sandstone was first developed many years ago by the Wise Coal and Coke Co. at Dorchester, a mile west of Norton, and for that reason the name "Glamorgan" is here abandoned and the bed given the name of Dorchester from the place at which it was first worked. The bed has in the past received many local names, such as "Norton No. 2," "Haskell No. 3," "Esserville Big Dirt Seam," and "Gladeville." The Dorchester bed is called the Cedar Grove by the West Virginia Geological Survey.

The best section of the Dorchester coal bed is in central Wise County just north of the upturned rocks of Powell Mountain. On Guest River in the vicinity of Norton the bed averages 60 to 70 inches of coal and on Powell River, 56 inches. The detailed section of the Dorchester bed varies greatly, even in small areas, and often changes rapidly within a single mine. The partings range from 1 inch to many feet and at many places split off benches of the bed that are too thin to work or too close to the main bed to be recoverable if the larger bed is mined. Such is the case at Glamorgan, where a notable split in the bed occurs. At Esserville the bed is parted near the middle by clay varying from 2 to 8 feet thick, hence the local name, "Esserville Big Dirt Seam." The Dorchester bed is 3 to 3½ feet thick with parting from 1 inch to 1 foot in the Bear Creek basin, and 1 foot, 6 inches to 2 feet, 6 inches thick, including partings, on Indian, Dotson, and Birchfield creeks, and on the forks of Bowlecamp Creek.

The Dorchester coal bed is mined by several large companies in central Wise County and as a coal producer ranks creditably with the Imboden and Upper Banner beds. The Wise Coal and Coke Co. at Dorchester, the Norton Coal Co., at Norton, the J. A. Esser Coke Co., at Esserville, and the Stonegap Colliery Co. at Glamorgan, are among the larger producers of the Dorchester coal. Mining on the Dorchester bed is confined almost entirely to the basins of Upper Powell and Guest rivers and Bear Creek.

The coal is an excellent coking coal, but locally runs too high in sulphur to be used for metallurgical coke. In general it is a coal of good heating value, running as high as 14,000 B. t. u.

LYONS COAL BED.

A 2½ to 3-foot bed of coal, 40 feet above the Gladeville sandstone, outcrops in the Upper Powell River and Bear Creek basins that is called the Lyons bed, being the extension of the Lyons bed in Dickenson County. The bed is probably an upper bench or split of the Dorchester bed. In

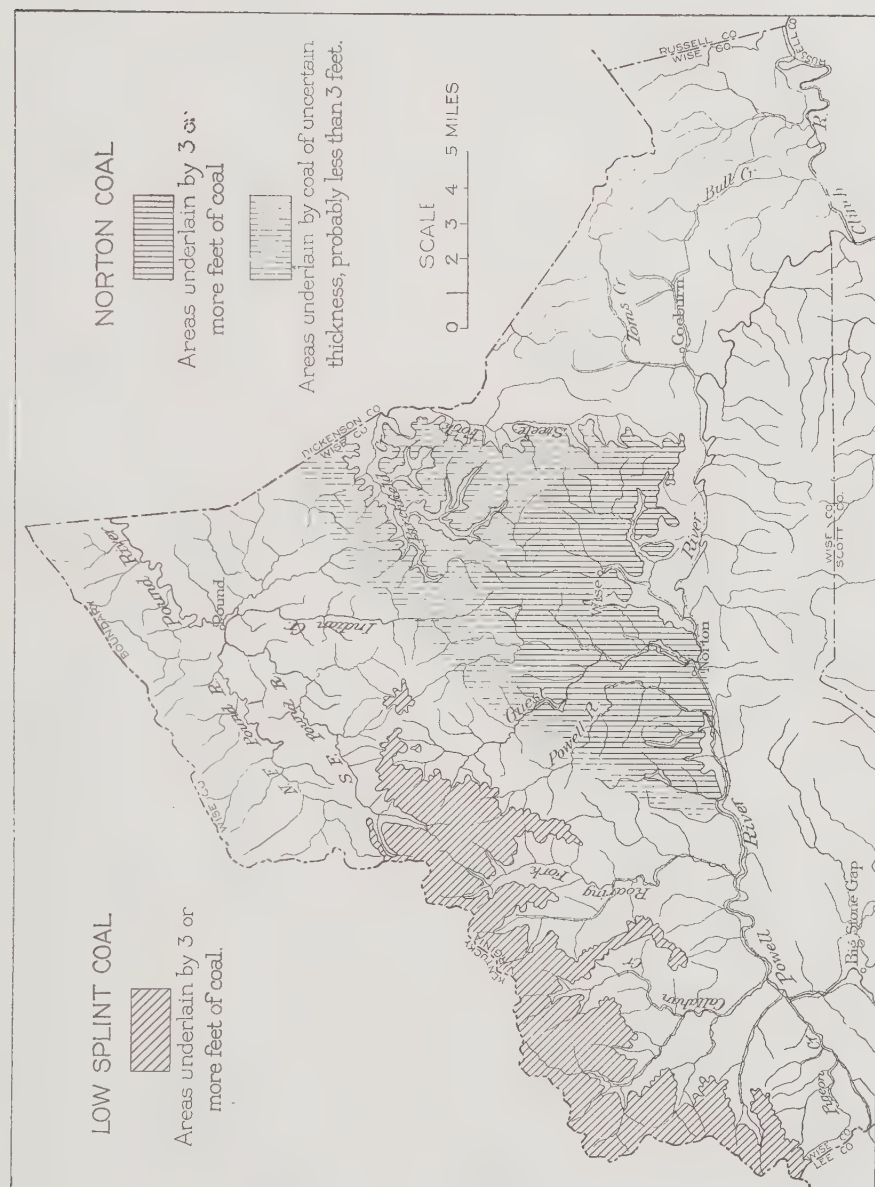


Fig. 11.—Sketch map of Wise County showing areas in which the Norton and Low Splint coal beds contain 3 feet or more of minable coal.

Dickenson County the coal is of local importance only and in Wise County the bed is little better, being able when coal is in great demand to support a few wagon mines. The bed is usually separated from the Dorchester by clay shale and is overlain in places by a thin, white sandstone. The thinness of this bed makes it of slight importance in Wise County.

BLAIR COAL BED.

The Blair coal bed lies 90 to 120 feet above the Gladeville sandstone and is of widespread occurrence in central and northern Wise County. The areas in which the bed is of workable thickness lie largely in the central part of the county, in the Upper Guest River basin, Upper Powell River basin, and in the Bear Creek basin. The Blair was so named by Butts,¹ because it was opened at the mouth of Lick Branch of Indian Creek by a man of that name. The bed is probably the Bens Creek bed of the West Virginia Geological Survey. Locally the Blair is called the "Norton No. 7 bed" and the "Haskell No. 1" or No. 3-a bed. The Blair bed is separated from the Lyons coal bed in large part by soft sandstone.

The Blair coal bed is at its best in the vicinity of Esserville, where it approaches 4 feet in thickness, without a parting. The coal here is hard but clear and one of the best coking coals in the county. On Powell River the Blair is 2½ to 3 feet thick, usually unparted. In the north-central section of the county the bed is parted by 10 feet of shale into an upper 2-foot and a lower 3 to 5-foot bench. The Blair is minable in the Bear Creek basin and to a small extent on McFall Fork, and Indian Creek, but is too thin or too much parted to be workable in the remaining part of the Pound River drainage basin.

The chief mining operation in the Blair bed is the J. A. Esser Coke Co.'s mines at Esserville. The bed is also opened at Dorchester by the Jordon mine of the Wise Coal and Coke Co.

CLINTWOOD COAL BED.

The next commercially important coal bed is the Clintwood, 70 feet above the Blair and 160 to 200 feet above the Gladeville sandstone (see fig. 8). The bed is everywhere overlain by a massive sandstone, herein named Addington sandstone, which is 20 to 40 feet thick and which either rests upon the coal bed or is separated from it by only a few feet of shale. The

¹ The coal resources and general geology of the Pound Quadrangle in Virginia, Virginia Geol. Survey Bull. IX, p. 29, 1914.

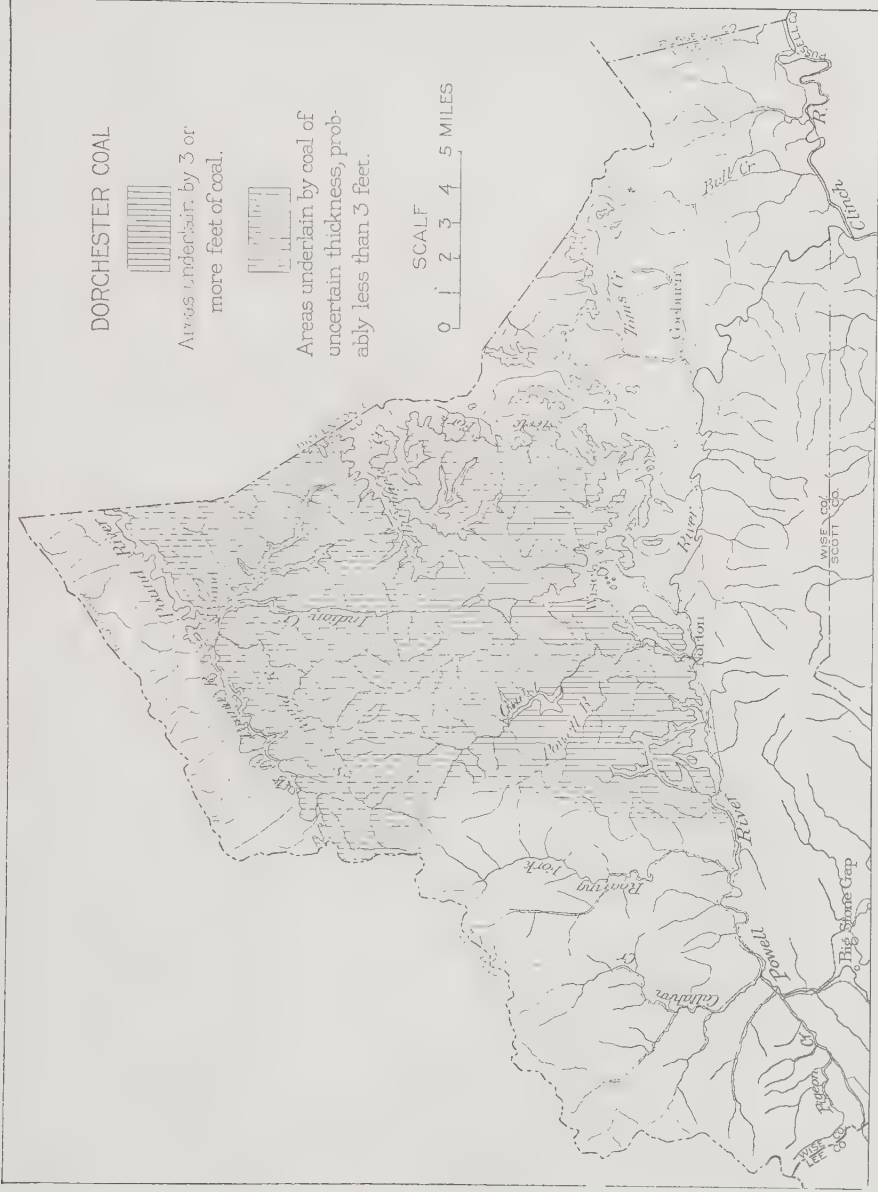


Fig. 12.—Sketch map of Wise County showing areas in which the *Dorchester* coal bed contains 3 feet or more of minable coal.

bed is named for Clintwood, the county seat of Dickenson County, where the bed ranges in thickness from 4 to 11 feet. The Clintwood is the same as the Matewan coal of the West Virginia Geological Survey and the Teds Creek bed on Rocklick Creek and vicinity in Kentucky. The bed is locally known as the "Norton No. 8 bed" and the "Big Dorchester" bed.

The great thickness of the Clintwood coal bed extends west from Clintwood into Wise County as far as Indian Creek. From Indian Creek to the south and west the bed is widely split, and in the vicinity of Lipps it is separated into two benches 20 feet apart. Farther south the parting decreases and from Sutherland to Dorchester and Glamorgan to Norton the bed is 4 to 5 feet of coal with a middle parting of shale or clay 1 to 5 feet thick. The large parting in the Clintwood bed is persistently present throughout the south-central part of the county. The bed has been extensively prospected in northern Wise County by the Clinchfield Coal Corporation and in southern Wise County by the Wise Coal and Coke Co., and the character of the bed and its partings is thus well known.

The bed is mined at Dorchester by the Wise Coal and Coke Co. It was also formerly mined at Norton. The Clintwood is now opened at many localities by small wagon mines or pits to supply fuel for local needs.

ADDINGTON COAL BED.

A coal bed in central and northern Wise County is commonly found overlying the massive Addington sandstone and is called the Addington coal bed. It is of local importance only, seldom exceeding 2 feet in thickness and has not been seen to exceed 3 feet in thickness.

ROCKY FORK COAL BED.

The Rocky Fork coal bed lies 40 feet above the Addington bed and occurs only on Rocky Fork of Guest River. The bed has a thickness ranging from 2 to 2½ feet, and is unimportant so far as commercial production is concerned.

IMBODEN COAL BED.

The Imboden coal bed in the lower part of the Wise formation is one of the notable coal beds of Wise County, both in thickness and quality of coal and the many mines now working it. The bed is now known to be the same as the Lower Bolling coal bed of Butts in northern Wise County and hence

is the equivalent of the Lower Campbell Creek coal bed of Dickenson and Buchanan counties. The areal extent of the bed in Wise County is shown in figure 12.

The Imboden has its maximum development throughout the western basins of the county, reaching nearly 10 feet in thickness at Inman, on Looney Creek. The average thickness of the bed on Pigeon, Looney, and Callahan creeks is between 5 and 6 feet of coal, with 6 to 8 inches of parting. The bed has much the same section on Lower Roaring Fork that it has on the creek just mentioned, but below Potcamp Fork at Pardee, where it has been prospected by the drill is greatly parted. On Black Creek, upper Powell River and upper Guest River the Imboden bed lies high in the hills, and little of it now remains in those drainage basins. Where the bed is preserved, however, it is thick and has few partings. In the Pound River basin the Imboden bed ranges from 18 inches to 4 feet in thickness and is subordinate in importance to the overlying Kelly bed.

The stratigraphic position of the Imboden places it near the top of the lower third of the Wise formation. In western Wise County the bed is calculated to lie 650 feet above the Gladeville sandstone, an interval that decreases to 550 feet at Black Creek and 500 feet in north-central Wise County, and is probably as small as 450 feet in the northeast section of the county. The thinning of the strata intervening between the Gladeville sandstone and the Imboden coal bed is in almost the same proportion as observed in the northeastward thinning of the Lee formation in Wise County. The Imboden lies above a thick micaceous sandstone that makes prominent ledges in the southwestern section of the field. This sandstone in places, as on Black Creek, is hard and massive, resembling the Gladeville. A sandstone usually overlies the Imboden coal and separates it from the Kelly coal. The bed has been largely prospected on Buck Knob and Bowlecamp Knob by the Clinchfield Coal Corporation.

The Imboden coal bed at its type locality in the western basins carries few partings and consists of a high quality coking coal. The bed is featured by zones of crushed coal, called by the miners "curly coal," from the polished curved surfaces formed in the crushing and slipping of the coal within the weaker zones of the bed. The coal within these zones breaks out in shapeless blocks showing lustrous, rounded faces, when the bed is mined. The quality of the coal is not affected in the process. The normal coal is hard and well jointed.

The Imboden coal bed is being worked chiefly by the Stonega Coke and Coal Co., Virginia Iron, Coal and Coke Co., and the Blackwood Coal and

Coke Co. The mines are located on Pigeon, Looney, and Callahan creeks, and Roaring Fork. The coal bed was formely mined west of the mouth of Black Creek and in small outliers on upper Powell River drainage.

KELLY COAL BED.

The Kelly coal bed is workable throughout much of its extent in the county. It ranges in thickness from 18 inches to 5 feet and has been prospected in Bowlecamp and Buck knobs by the Clinchfield Coal Corporation under the name of "5-foot bed." The Kelly is the Upper Bolling coal of previous reports of this region.

The interval between the Kelly and the Imboden coal beds is extremely variable in south-central and western Wise County, ranging from a few inches to 70 feet. In northern Wise County the beds are more uniformly separated, the interval between them ranging from 20 to 40 feet. Above the Kelly bed is 50 to 80 feet of coarse micaceous sandstone, which, on Pound River especially, crops out for long distances as a low cliff or escarpment. The escarpment is conspicuous on the ridges along Indian Creek. The sandstone persists throughout the area underlain by the Kelly coal in northern Wise County. On South Fork of Pound River the coarse sandstone is overlain by 140 feet of shale and sandstone, capped by a 40-foot bed of sandstone.

The Kelly bed is mined for shipment only at Roaring Fork, where it is entered by one of the mines of the Blackwood Coal and Coke Co. The bed is opened locally by many country mines, particularly in the Pound River region.

LOWER STANDIFORD COAL BED.

In northern Wise County two coal beds of workable thickness outcrop 260 feet above the Imboden bed, or on an average of 810 feet above the Gladeville sandstone. The beds are 20 feet apart at their type locality on the South Fork of Pound River. They were named Upper and Lower Standiford by Butts for the man opening the beds at their type locality.

The Lower Standiford bed contains from 2 to 2½ feet of coal. It is nowhere thick enough to sustain a shipping mine under the present coal market conditions and is therefore of small commercial importance today.

The outcrop of the Lower Standiford coal bed is indicated on the geologic map for that portion of Black Mountain and Buck Knob, where the bed is fairly well known.

UPPER STANDIFORD COAL BED.

The upper of the two Standiford beds averages 3 feet of coal, with 1 to 5 inches of parting, and is a workable bed. The outcrop of the Upper Standiford has not been traced into the Callahan Creek basin or into other basins to the west, but comparative intervals suggest the correlation of the bed with the Wilson bed as it appears on the boundary line separating Wise County from Lee County. A bed of coal that is supposed to be the Upper Standiford and workable under favorable market conditions, has been opened at the head of Callahan Creek.

The Upper Standiford bed shows its best section on Critical Fork of Guest River, where it measures 3 feet, 10 inches of coal with only a small parting. The Wilson bed on Pigeon and Looney creeks ranges from 3 feet, 3 inches on the former to 2 feet, 4 inches in thickness on the latter creek. The Wilson bed is 300 to 330 feet above the Imboden in the basins of these streams.

TAGGART MARKER COAL BED.

A coal bed lying 30 to 50 feet below the Taggart bed and approximately 410 feet above the Imboden bed has been called the Taggart Marker as it indicates the proximity of that valuable bed. A thick fine-grained sandstone usually overlies the Taggart Marker bed and not uncommonly constitutes all the rocks between it and the Taggart.

The Taggart Marker bed is known in the Roaring Fork basin and in all the basins to the west, but it was not seen in the Pound River country. The most promising occurrence of the bed is in Ninemile Spur, where it has a thickness of 3½ feet of clear coal.

The bed is mined at Dunbar by the Stonega Coke and Coal Co., this being the only shipping mine in the bed.

The outcrop of the Marker bed is not given on the geologic map but can readily be inferred from the Taggart outcrop, as the two could not be differentiated on a map of this scale.

TAGGART COAL BED.

The Taggart coal bed ranks as one of the most valuable coal beds in Wise County (see fig. 1). Its average heating value is greater than any other bed in the county and it extends under many square miles with a thickness of coal ranging from 5 to 6 feet, with less than 1 foot of parting. The outcrop of the bed has been traced throughout its entire extent in Wise County and into the adjacent part of Lee County and mines have been

driven in it through Black Mountain into Kentucky, where the bed is correlated with the "C" bed of the United States Coal and Coke Co. at Lynch, in Harlan County. Locally, the bed is known as the "Roda Seam" or "Roda coal" for Roda, a mining town in the Callahan Creek basin. In Lee County the bed is called the "Keokee bed" and is correlated by Giles¹ with the "No. 5" bed in the Pocket in that county. White arkosic sandstone crops out above and below the Taggart coal, but thin beds of shale usually separate the coal from the sandstone.

The interval between the Taggart and the Imboden beds varies, with the largest interval in the region of Nine-mile Spur and decreasing to both the east and the west. On Looney Creek and Preacher Creek, boreholes show that the interval is almost exactly 400 feet; on the north of Callahan Creek and Roaring Fork the interval is 450 feet; and in the Pound River basin it rapidly decreases to approximately 350 feet.

The Taggart coal bed is one of the thickest coal beds in Black Mountain and its spurs in the western basins of Wise County. Roda, on Mudlick Creek of Callahan Creek, might be regarded as the type locality of the bed. At this locality the bed ranges from 5 to 6 feet thick, consisting of a soft, well jointed coal possessing a high luster, and mines out in large blocks. The coal burns with an intensity characteristic of cannel coal. The Stonega Coke and Coal Co. has several mines in the bed at Roda and one at Dunbar. The Virginia Iron, Coal and Coke Co. is mining the bed on Looney Creek.

The Taggart is persistent in Black Mountain at the head of Pound River but is split into two or more benches, none of which is a particularly desirable coal bed.

LOW SPLINT COAL BED.

The first persistent coal bed above the Taggart is the Low Splint, the interval between them ranging from 200 to 240 feet (see fig. 11). The bed crops out continuously throughout the Black Mountain region and lies in an isolated tract near the top of Buck Knob, where it was prospected by the Clinchfield Corporation as the "Buck Knob" bed. It averages $2\frac{1}{2}$ to $3\frac{1}{2}$ feet of coal and 6 to 12 inches of parting.

The bed has been prospected on Roaring Fork by the Virginia Coal and Iron Co. It is, however, not mined for shipment anywhere in the county but is opened by several local mines.

¹ Giles, A. W., The geology and coal resources of the coal-bearing portion of Lee County, Virginia: Bulletin Virginia Geological Survey (in press).

PHILLIPS COAL BED.

The Low Splint bed on the South Fork of Pound River is succeeded by 260 feet of shale and sandstone at the top of which is a coal bed named by Butts the Phillips coal because it has been opened on the Ambrose Phillips farm, at the head of South Fork of Pound River (see fig. 9). The bed at its type locality is reported to be 26 inches thick, without a parting. The Phillips coal bed may be the same as the Dean coal of the Kentucky Geological Survey.

The Phillips bed is 2 feet thick on Looney Creek, consisting of clear, hard, almost splinty coal. It outcrops between massive sandstones and in this region is 250 feet above the Low Splint coal. On Callahan Creek it is thin and scarcely workable. In the Pound River basin of Black Mountain the bed is persistent but averages only 2 feet of coal. The bed is not mined in Wise County.

The Phillips coal bed lies 390 feet below the Pardee bed. A carefully measured section on South Fork of Pound River shows the following thin coal beds between the Phillips and the Pardee:¹

Eighty feet above the Phillips is an 18-inch bed of coal; 210 feet above the Phillips is a 1-foot bed; 225 feet above is a 2-foot bed; and 340 feet above the Phillips, or 50 feet below the Pardee bed, is a 6-inch bed of coal. Between 210 and 225 feet above the Phillips coal is an 8-inch limestone bed, which is the only limestone that was seen in the entire Pennsylvanian section in Wise County.

PARDEE COAL BED.

The highest bed in the Wise formation, that is now being mined in Wise County is the Pardee coal bed, which lies 850 feet above the Taggart bed and 400 to 450 feet below the Harlan sandstone (see fig. 10). The Pardee bed is named for Pardee on the headwaters of Potcamp Fork of Roaring Fork, where the bed is now mined by the Blackwood Coal and Coke Co. The Pardee is the "Limestone" and "Haddix" coal beds of the Kentucky Geological Survey and has locally been known as the Parsons bed. It lies 2,800 to 3,100 feet above sea level and therefore near the summit of Black Mountain and its highest spurs. Above the Pardee bed is about 100 feet of shale overlain by rather coarse-grained flaggy sandstone 300 feet thick.

¹ Butts, Charles, Coal resources and general geology of the Pound Quadrangle in Virginia, Bull IX: Virginia Geol. Survey, 1914, p. 12.

The Pardee coal bed reaches its maximum thickness of 9 to 11 feet of coal with small and relatively insignificant partings in the Roaring Fork basin. From the head of Roaring Fork and its branches, the bed splits both to the east and to the west. Thus on Callahan Creek the main bench of the bed ranges from 4 to 4½ feet of coal with 3 to 6 inches of partings. Northeast of Pardee the bed thins to 5 feet of coal with 1 foot of partings, well scattered throughout the section. The partings, however, are extremely variable and at places split the bed into two or more benches many feet apart.

The Pardee bed is mined in Wise County only at Pardee.

MORRIS COAL BED.

A coal, which is called the Morris bed, has been opened on Callahan Creek, about 350 feet above the Pardee. It is best developed in Bluff Spur, where it averages 5 to 5½ feet in thickness and it is 3 to 4 feet thick on Roda Spur of Black Mountain. The Morris bed was not seen in the Roaring Fork basin or in any basin to the east or northeast of Roaring Fork. On Looney and Pigeon creeks west of Callahan Creek the bed is present, but measured sections were not obtained.

HIGH SPLINT COAL BED.

The High Splint coal bed is 350 to 450 feet above the Pardee bed, the maximum interval holding for the extreme western end of the county and the minimum interval prevailing throughout the major part of the Black Mountain area (see fig. 8). At Pardee it is 320 feet above the Pardee coal. The bed lies so high on Black Mountain that it has a comparatively small extent in Wise County. The basal bed of the Harlan sandstone, 20 to 40 feet above the coal, makes a conspicuous escarpment everywhere above the High Splint bed.

The bed is a genuine splint coal 4 to 5 feet thick, usually without a parting. It is well developed and constant in character throughout the Roaring Fork basin, as shown by numerous prospects, and it is seldom broken by partings.

The bed was mined at Pardee by the Blackwood Coal and Coke Co., the only mine in the county in this bed, but the operation is now closed. The general inaccessibility of the bed will prevent it from competing successfully with lower and thinner beds, at the present status of the coal market.

No coal beds of workable thickness were seen above the High Splint bed.

COAL MINING.

PRESENT OPERATIONS.

Coal mining in Wise County is a well-organized industry and the larger companies keep abreast of the times in their mining equipment. The mines are in large part electrically equipped; cutting machines of the latest design are used to mine the coal, and high-powered electric motors are used to haul it to the tipples. The tipples serving the majority of the mines are of late construction and are provided with shaker screens to make three sizes of coal—lump, egg, and slack.

Among the larger coal-mining organizations in the county are the following: the Stonega Coke & Coal Co., Big Stone Gap, and Philadelphia, Pa.; the Virginia Iron, Coal & Coke Co., Toms Creek, and Roanoke, Va.; the Wise Coal & Coke Co., Dorchester; the Blackwood Coal & Coke Co., Blackwood; the Clinchfield Coal Corporation, Dante; The Norton Coal Co., Norton; the Stonegap Colliery Co., Glamorgan; the Hawthorne Coal Co., Norton; the Intermont Coal & Iron Co., Big Stone Gap; the Gladeville Coal Co., Wise; the J. A. Esser Coke Co., Esserville, and the Robert Fleming & Co., Norton. Thirty-seven other organizations and individuals are listed by the Division of Mineral Resources of the United States Geological Survey as producing coal in 1920, but so many of the smaller companies, and particularly individual operators have sold or closed their mines that it would be of little value to publish the list. Many of the smaller mines were abandoned in the fall and winter of 1920, immediately following the great drop in the price of coal.

The types of mines and methods of mining common to southwest Virginia have been described at considerable length by C. K. Wentworth in the consideration of the coals of Russell County, Va.,¹ and the description will not be repeated here in detail. The mines of Wise and Scott counties are predominantly drift mines, there being only a few slope mines in the field. A drift mine may be described as any mine whose main entry enters a coal bed approximately horizontally. A slope mine is any mine whose main entry slopes into the ground, whether it slopes down the dip of an inclined coal bed or slopes down to meet a flat-lying coal bed that does not outcrop in the vicinity. There are no mines in the field whose main entries are vertical shafts. Probably 99 per cent of the mines in the field are drift mines. An example of a slope mine is the No. 10 mine of the

¹ Wentworth, C. K., *Geology and Coal Resources of the coal-bearing portion of Russell County, Va.* Bull. XXII, Va. Geol. Survey, 1922, pp. 137-150.

Norton coal Co. at Norton. The main entry here slopes a vertical distance of 57 feet to meet a nearly flat-lying coal bed that is below stream level.

The "room-and-pillar" method of mining is universally used in the field. By this system, coal is first mined from a number of comparatively small places called rooms, which are usually driven at right angles off the main entry or side entries. Large bodies of coal, called pillars, are left in place between the rooms to sustain the roof. Before abandoning a mine this coal is removed, if possible, allowing the roof of the mine to settle.

A special application of the "room-and-pillar" system is employed where the main entry of a mine extends along the strike of a dipping coal bed. The J. T. S. Coal Corporation's mine on Little Stony Creek is a mine of this type, the coal bed here dipping 37 to 39 degrees. The main entry is horizontal, going in on the strike of the coal bed, and rooms are driven up the rise at intervals of about 100 feet. The miner in advancing the face of his room loosens the coal either by pick or shooting from the solid and permits the coal to slide by gravity into a bin fastened at the entrance of the room. From this bin the coal can be loaded at will directly into mine cars in the main entry. Such highly inclined coal beds as found at the J. T. S. Coal Corporation's mine, however, are almost entirely confined to the very narrow zone of greatly disturbed rocks along the southeast margin of the coal field, and the coal beds in this zone are little mined.

FUTURE DEVELOPMENT.

The coal reserves of Wise and Scott counties, as shown on a following page are large enough to permit of greater development than that which prevails at the present time.¹ Large tracts of coal-bearing lands have not yet been touched. Nevertheless, it requires no careful study of the sections of the coal beds in the detailed descriptions of the drainage basins, to see that the coal beds of the field as a whole are notably thinner in the virgin areas than in the areas now being worked. Thus, in the Pound River drainage basins and on Powell Mountain, areas of practically no mining at the present time, large numbers of carefully faced prospects and boreholes clearly show beds of a thickness inferior to those on Callahan Creek, Roaring Fork, upper Powell River, upper Guest River,

¹ It should be pointed out here that there is unquestionably an over-production of coal, particularly bituminous, at the present time and new mines are not encouraged. The opening of new mines in times of over-production and in fields that are already well taken care of by existing mines reacts to the great disadvantage of the coal industry in general.

and Toms Creek, all centers of mining. The extensive development of the territory tributary to Powell and Guest rivers is largely if not wholly due to the great thickness and purity of the coal beds.

The future development of the coal field of Wise and Scott counties will naturally divide itself into two periods—the first period including the present and near future, and the second period the more distant future. The first period of the development will witness the progress of mining on Powell and Guest rivers and in eastern Wise County until the important workable beds are largely exhausted in those areas; the second period will then witness the opening up by railroads of the present inaccessible fields and the mining of the inferior coal beds. That these periods in the future mining of the coal beds of Wise and Scott counties will overlap is certain, but it is quite unlikely that the overlap will be great. It is almost inevitable that transportation facilities into the Pound country, or as far as is possible, into the Powell Mountain field, will be delayed until the coal resources in the accessible basins of this and neighboring regions are so impoverished that new supplies of coal will have to be reached notwithstanding the expense.

COAL PRODUCTION.

COAL MINED IN WISE COUNTY.

Coal was first mined and shipped from Wise County in 1892, immediately following the arrival of the railroads. It was December of that year, however, before any coal was actually shipped and as a consequence the amount sent out was only about 2,000 tons. From that year on the production of coal from Wise County grew with great rapidity, reaching its highest annual production for the 30 years from 1892 to 1921, inclusive, in 1920 with a production of 6,062,325 short tons of coal. The total amount of coal mined in Wise County for the 30-year period, including the 188 tons recorded for the year 1889, is 86,098,415 tons. Assuming that an amount of coal equal to one-fourth of all the coal that has been taken out was lost by abandoning pillars in old mines, by mining out thick beds under thin beds and allowing the roof to drop, and by other sources of waste, at least 107,623,000 tons of the coal originally in the ground has been removed or lost. The figures of annual production, taken from Mineral Resources of the United States¹ for those years, are given in the following table, along with the figures showing valuation of the coal.

¹ Mineral resource reports of the United States Geological Survey.

*Amount and Value of Coal and Amount of Coke Produced in Wise County,
Virginia from 1889 to 1922, inclusive.*

Year.	Total quantity of coal produced.	Total value of coal.	Average price per ton.	Amount of coal made into coke within county.
1889	188	\$ 188	\$1.39	.....
1890 .....	.....	.....	.....	.....
1891 .....	.....	.....	.....	.....
1892	2,000	.....	.....	.....
1893	126,216	113,436	.90	.....
1894	330,731	230,637	.70	.....
1895	336,593	192,713	.57	11,044
1896	357,607	217,519	.61	95,608
1897	712,011	469,637	.66	314,007
1898	992,723	562,418	.57	512,818
1899	1,232,613	793,174	.64	662,585
1900	1,363,570	1,144,715	.84	739,231
1901	1,918,693	1,537,667	.80	1,064,720
1902	2,422,417	1,782,583	.74	1,522,620
1903	2,563,285	2,322,855	.90	1,538,602
1904	2,514,133	2,024,752	.81	1,404,823
1905	2,990,698	2,525,635	.84	1,933,498
1906	3,041,225	2,915,914	.95	1,977,301
1907	3,145,848	3,066,075	.97	1,962,288
1908	2,558,874	2,204,093	.86	1,487,136
1909	2,841,448	2,463,588	.87	1,468,005
1910	3,730,992	3,274,809	.88	1,805,467
1911	3,754,360	3,301,984	.88	1,154,799
1912	3,500,174	4,094,905	.91	1,335,582
1913	5,103,559	4,899,390	.96	1,738,175
1914	4,620,702	4,345,204	.94	1,182,793
1915	4,186,309	3,874,099	.93	834,660
1916	5,228,945	5,060,442	.97	1,802,218
1917	5,427,455	9,727,637	1.79	1,954,093
1918	5,514,132	13,466,647	2.44	1,527,849
1919	5,049,436	12,643,947	2.50	1,485,313
1920	6,062,325	22,947,215	3.79	1,622,499
1921	3,469,153	10,656,000	3.07	422,521
1922	5,022,866	12,205,000	2.43	584,212
Total	91,121,281			
Estimated loss in mining	21,524,585			
Total exhaustion	112,645,866			

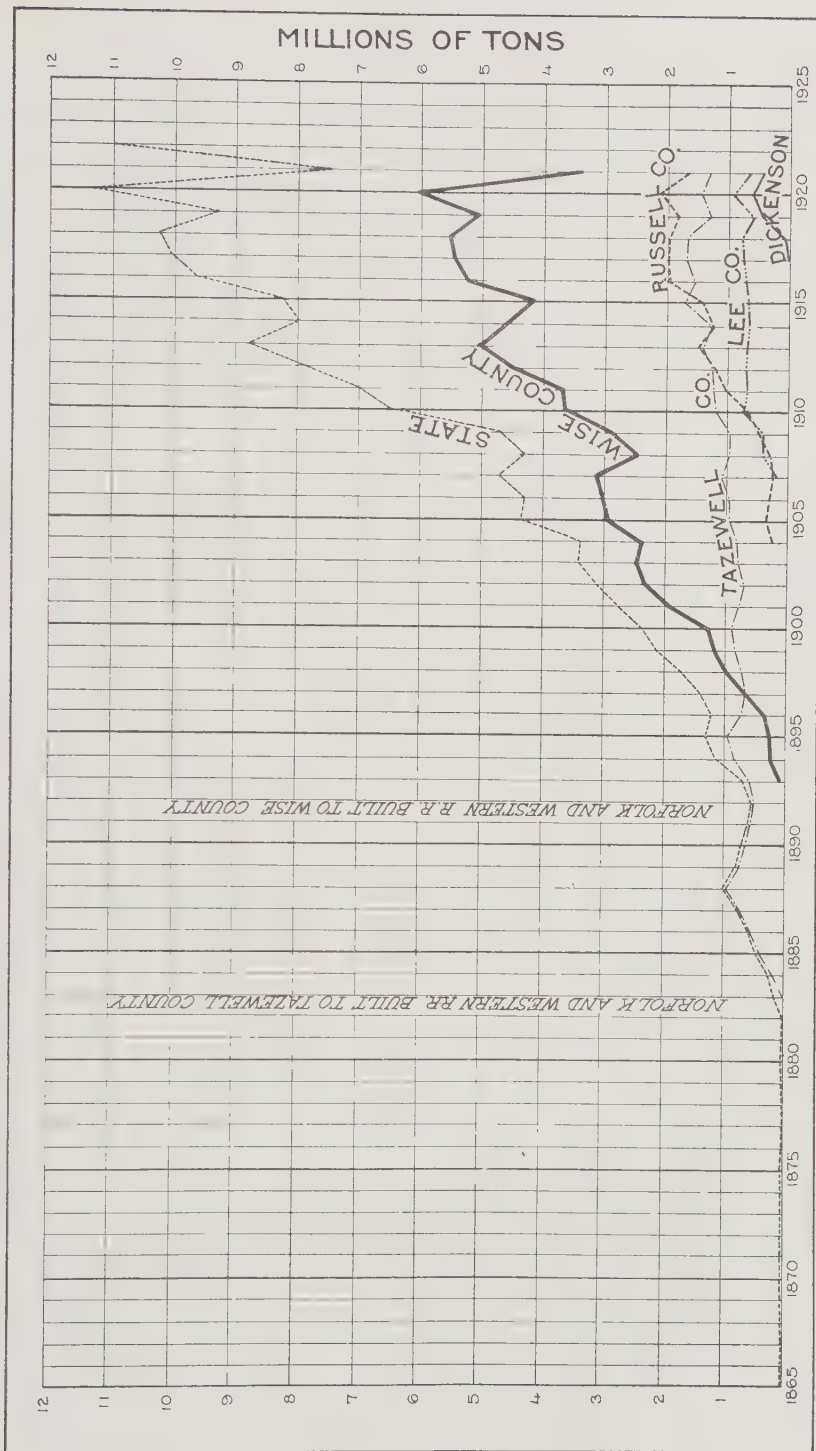


Fig. 13.—Graph showing annual production of coal in southwest Virginia by counties from 1865 to 1922.

The supremacy of Wise County over the other counties of Virginia in the production of coal is graphically shown in Fig. 13. The table of annual production and the graph showing annual county production clearly point out the "banner" and "lean" years of the mining industry. The years 1913 and 1920 are two of the notable "banner" years, whereas 1915, 1919 and 1921 are notably "lean" years. Lack of cars and labor, and low prices paid for coal were the chief factors in producing the "lean" years. The abnormally high price paid for coal in 1920 made it a year of great production. Notwithstanding the great production for that year it would have been considerably larger had more railroad cars been available to carry away the coal.

The amounts of coal produced from the various coal beds in Wise County are given below in a table and in Fig. 14 for the three-year period, 1918 to 1920, inclusive. The circle in Fig. 14 shows the average production for the three-year period, and clearly brings to the front the important producing beds of the county. The diagram shows that the Imboden, Kelly, and Upper Banner beds produce more than 60 per cent of the entire county production, and that the Imboden, Kelly, Upper Banner, Taggart Marker, Taggart, Pardee, Dorchester, Blair, and Clintwood produce more than 90 per cent of the coal. More than 99 per cent of the coal comes from fifteen beds shown in table and Fig. 14.

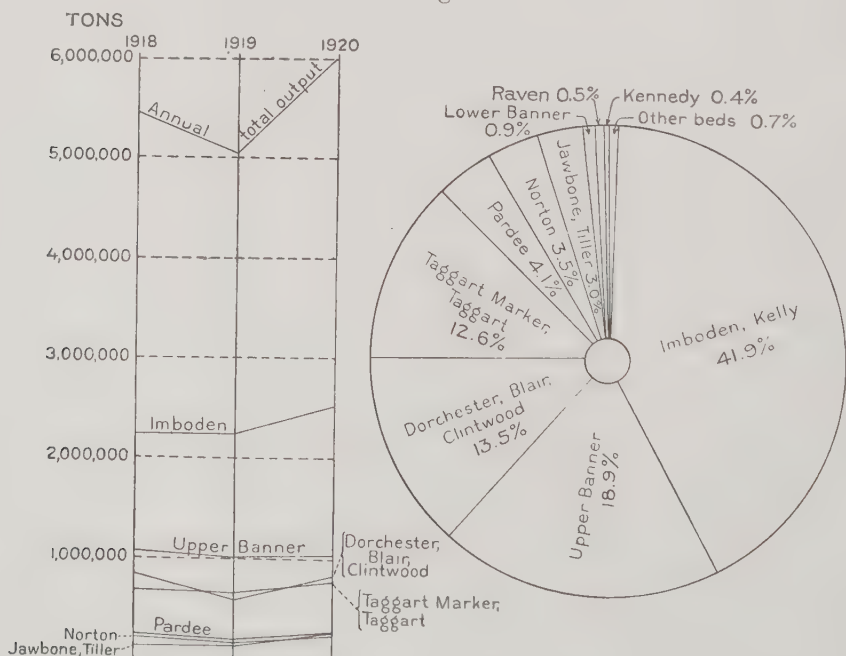


Fig. 14.—Diagram showing amounts of coal produced from various coal beds in Wise County for years 1918, 1919, and 1920.

Production by coal beds for the years 1918, 1919, and 1920.

	Coal Beds	1918	% of total prod.	1919	% of total prod.	1920	% of total prod.	Total	% of total prod.
1	Pardee	218,701	4.0	190,054	3.8	267,978	4.4	676,733	4.1
2	Taggart	674,941	12.2	641,920	12.7	786,697	13.0	2,103,558	12.6
	Taggart Marker								
3	Imboden	2,214,446	40.3	2,233,429	44.2	2,523,576	41.6	6,971,451	41.9
	Kelly								
4	Dorchester	833,222	15.1	594,309	11.8	821,679	13.6	2,249,210	13.5
	Blair								
	Clintwood	206,200	3.7	154,061	3.1	215,388	3.6	575,649	3.5
5	Norton								
6	Upper Banner	1,056,372	19.2	1,004,770	19.9	1,075,776	17.7	3,136,918	18.9
7	Lower Banner	54,725	1.0	54,434	1.1	39,263	0.6	148,422	0.9
8	Kennedy	39,759	0.7	12,477	0.2	21,578	0.4	73,814	0.4
9	Raven	39,904	0.7	17,435	0.3	17,322	0.3	74,661	0.5
10	Jawbone	136,576	2.4	137,082	2.7	231,971	3.8	505,629	3.0
	Tiller								
		5,474,846	99.3	5,039,971	99.8	6,001,228	99.0	16,516,045	99.3
11	Other beds	39,286	0.7	9,465	0.2	61,097	1.0	109,848	0.7
	Total output	5,514,132	100.0	5,049,436	100.0	6,062,325	100.0	16,625,893	100.0

ESTIMATE OF ORIGINAL TONNAGE OF COAL BEFORE MINING BEGAN.

In attempting to estimate the tonnage of coal in any field, one must first consider the object to be attained by such an estimate. Is it to show the amount of coal that could be mined under present commercial and mining conditions, or is it to show the amount of coal ultimately available? An estimate of the coal in a given field that can be mined under present conditions has great value, but as conditions change rapidly, an estimate that might be considered satisfactory today might not meet the case at all tomorrow.

The people of the State of Virginia as well as those of the Nation are more interested in an estimate of the total amount of coal that will ultimately be available than they are in the amount that can be mined under present conditions, for the latter is of transient value only, while the former is of lasting importance. If the estimate is to include all of the coal that ever will be mined, then it is evident that thinner and more irregular beds must be included than have heretofore been taken into consideration. The only clue to the minimum thickness of coal beds that should be included is that afforded by mining practice in fields in which the thicker coal beds have been mined out and operations are today being carried on in thinner beds and at greater depth than heretofore has been regarded as possible. After an exhaustive search of the literature, the United States Geological Survey has adopted 14 inches as the minimum thickness of high grade coal to be considered in the classification of the public lands and as this thickness has been applied in most estimates of ultimately available coal, it will be used as the basis for all estimates in Wise and Scott counties. The tonnages in the following table, therefore, include all beds or parts of beds in which there are 14 inches or more of minable coal, but do not include thinner beds or parts of beds that could not be mined profitably because of the position and thickness of partings or because of other factors. The calculations of tonnage are based on an estimate of 1,770 tons per acre for each layer of coal 1 foot thick, which is equivalent to a density of 1.3 and to a weight of 81.3 pounds per cubic foot.

The estimates of coal tonnage in Wise and Scott counties were prepared for the main drainage basins of the field. Planimeter¹ measurements were made on the geologic map of the area in acres of each basin underlain by a particular coal bed which shows in outcrop in the basin, and the average thickness of the bed was obtained from sections measured in the basin. Only the tonnages of the more important beds of the largest

¹ An instrument for the determination of areas of irregular outline.

Estimates of Original Tonnage of Coal in Wise and Scott Counties, in Beds 14 Inches or More in Thickness.

Basin.	Area of basin in acres.	Bed.	Acreage of coal.	Average thickness. Ft. In.	Tonnage of beds.	Total tonnage.
Pigeon and Looney creeks.	9,610	Imboden.	7,460	5 11	77,882,400	253,900,000
		Taggart.	2,990	5 8	30,636,400	
		Other beds.	.....	.....	145,381,200	
Callahan Creek.	19,640	Imboden.	17,765	6 2	198,257,000	748,036,000
		Taggart.	11,810	5 6	116,919,000	
		Other beds.	.....	.....	433,860,000	
Roaring Fork.	19,720	Imboden.	15,970	6 0	172,454,500	525,862,000
		Taggart.	8,385	4 6	67,918,500	
		Other beds.	.....	.....	285,489,000	
Black Creek.	4,785	All beds.				78,743,000
Upper Powell River.	7,535	Dorchester.	7,185	6 0	58,181,400	285,741,000
		Clintwood.	5,945	4 6	64,184,400	
		Other beds.	.....	.....	163,375,200	
Upper Guest River.	17,740	Norton.	17,520	4 0	126,144,000	608,094,000
		Dorchester.	16,100	5 5	156,926,700	
		Clintwood.	13,220	4 6	107,082,000	
Bear Creek.	9,310	Other beds.			217,941,300	151,722,000
		All beds.	.....	.....	.....	
						
Middle Guest River.	3,165	All beds.				34,396,000
Lower Guest River.	4,135	All beds.				23,344,000

basins are given in detail; that of the thinner or less regular beds being combined in a single item. Although carefully prepared, these estimated tonnages are at best only approximations. They are based on the assumption that a coal bed maintains throughout an entire basin the average thickness displayed at its outcrop, an agreement which probably seldom, if ever, is attained. Every factor employed in computing the tonnages given below was given the most careful attention and it is felt that the total tonnage figure is more likely to indicate less rather than more coal than is actually present within the field. In preparing the table no allowance has been made for coal already mined and the figures given represent the estimates of coal prior to mining operations.

Since mining operations have begun in Wise County, 86,098,415 short tons of coal have been extracted up to and including the year 1921. This represents 1.5 per cent of all the coal originally present in the county. This is graphically shown in Fig. 15, in which the larger cube represents approximately the amount of coal now in the ground compared with a smaller cube representing approximately the amount of coal mined.

Assuming 75 per cent recovery, which is a fair estimate for favorable mining conditions throughout a field at large, the amount of minable coal remaining in Wise County at the beginning of 1922 was approximately 4,400,000,000 short tons. At the present rate of consumption of bituminous coal in the United States, Wise County could supply the country for about $9\frac{1}{2}$ years. If the annual production of Wise County averaged 4,000,000 tons, the county could produce coal for 1,100 years, or if, as in the banner year of 1920, it produced 6,000,000 tons a year, the county

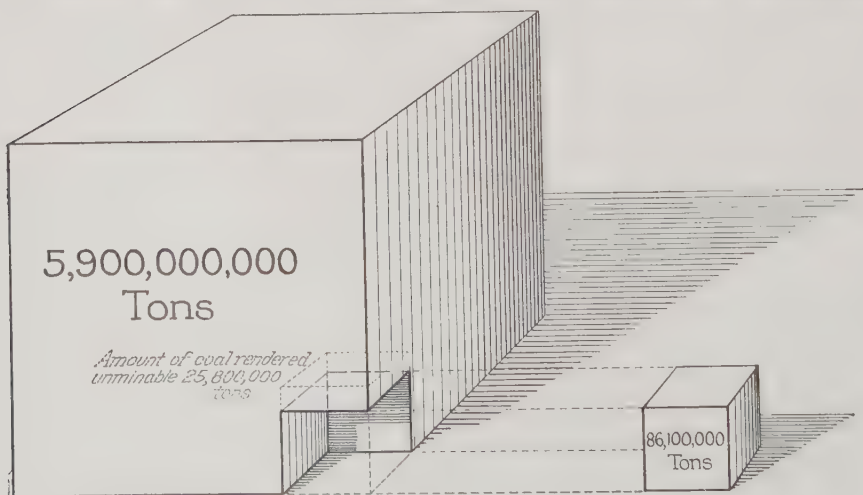


Fig. 15.—Diagram comparing total amount of unmined coal in Wise County to total amount mined up to and including year 1921.

Estimates of Original Tonnage of Coal in Wise and Scott Counties, in Beds 14 Inches or More in Thickness.

Basin.	Area of basin in acres.	Bed.	Acreage of coal.	Average thickness. Ft. In.	Tonnage of beds.	Total tonnage.
Toms and Little Toms creeks.	10,425	Upper Banner. Other beds.	5,970	6 0	64,476,000 154,026,000	218,502,000
Indian Creek.	7,240	All beds.	.....	.....	.....	98,574,000
South Fork Pound River.	11,360	All beds.	.....	.....	.....	260,529,000
North Fork Pound River.	12,245	All beds.	.....	.....	.....	67,390,000
Pound River.	10,385	All beds.	.....	.....	.....	58,467,000
Bowlecamp Creek.	8,945	All beds.	.....	.....	.....	138,373,000
Birchfield Creek.	13,565	All beds.	.....	.....	.....	170,044,000
Cranesnest River.	12,875	Upper Banner. Other beds.	11,260	5 0	101,340,000 64,803,000	166,143,000
Bull Run.	7,250	Jawbone. Other beds.	5,480	6 0	59,205,600 87,212,400	146,418,000
Russell Creek.	8,830	Jawbone. Other beds.	7,780	6 6	91,026,000 117,082,000	208,108,000
Powell Mountain field.	90,000	All beds.	.....	.....	.....	1,622,000,000
Total,	288,650		.....	.....	.....	5,864,386,000

could produce coal for about 730 years. The many factors influencing the rate of production of coal, such as the demand for coal, the availability of labor and cars, and mining conditions, make an estimate as to the life of any field a little better than a guess. Production will undoubtedly increase as long as thick beds of coal are readily accessible. As these beds approach depletion, however, the thinner and more inaccessible beds will become of value and will be mined, but the volume of tonnage of coal produced annually then will unquestionably decrease.

PHYSICAL AND CHEMICAL CHARACTERS OF THE COAL.

GENERAL STATEMENT.

The value of coal depends not only on its chemical, but also on its physical characteristics, and consequently a consumer of coal should take both of these factors into consideration when he makes a selection of the coal he is to purchase and use, and it is equally important for the producer and dealer to know the true value of the coal he handles. A chemical analysis together with a determination of the heat-producing value of a coal in a standard calorimeter will generally give sufficient data for the determination of the comparative values of coals.

As a large percentage of the coal mined in the United States is used directly or indirectly for the production of heat, it is important, when comparing coals for this use, to know their relative heat-producing values. These are given in the table just referred to under the heading of "Calorific Value" and it is expressed in British Thermal Units (B. t. u.'s), such a unit being the amount of heat required to raise one pound of water (at its maximum density of 68° F.) one degree Fahrenheit. Thus, the heat-producing value of Wise County coals range from 11,410 to 14,690 B. t. u.'s in the sample as it comes from the mine, which is approximately the same as the coal which reaches the consumer, and hence the true value of these coals, so far as heat-production is concerned will agree with the figures given in the table. Thus it is manifest that a coal with B. t. u.'s of 13,000 is less efficient than a coal with 14,000 B. t. u.'s. Expressed in percentages, the 14,000 B. t. u. coal is 7.7 per cent better than the other, and if the one with 13,000 B. t. u.'s is selling for \$5 per ton, the one with the 14,000 B. t. u.'s would be worth \$5.38 per ton.

The ordinary chemical analysis reveals a number of facts that are worth noting, because they tend either to enhance or detract from the value of the coal. Thus, the amounts of moisture and ash are important,

for though inert, they lessen the heating value of a coal materially; and the sulphur, though it can be burned, is a very bad ingredient in many respects. The volatile matter and the fixed carbon are important in their relative proportions, for to a certain extent they determine the rank of the coal and they are of importance in certain special uses.

The physical properties of coals are almost as important as the chemical, for to a certain extent they control the use of a coal. Thus, nothing but a blocky coal can be successfully used for domestic purposes, and fine coal, if of high calorific value, can be used for steam-raising if it is used in a plant equipped with automatic stokers.

In order, therefore, to determine the true value of a coal and the best use to which it may be put, it is necessary to know its chemical composition and its physical characteristics and balance these against the cost of mining and transportation to the place where the coal is to be used.

PHYSICAL CHARACTERISTICS OF WISE COUNTY COAL.

The coals of Wise County are generally hard and blocky and, when properly mined, reach the railroad cars in fairly large lumps. Lump coal of this character is well adapted to domestic use; to heating and steam-raising, but in modern plants the coal is generally crushed so as to be fired with automatic stokers; and to export trade where lump coal is generally demanded, on the theory that it contains fewer impurities and will stand transportation better than fine coal. If the coal is screened at the mine, as is generally the case, the fine coal may or may not be as clean as the lump coal. If it comes from a bed free from partings, it is generally relatively clean, but if it comes from a bed containing many partings of soft shale or clay, or if the roof is of this kind of material, the "slack" or fine coal is liable to contain a large amount of incombustible matter.

As stated in the description of the coal beds of this field, a number of the beds are characterized, in certain parts of the county, by laminated or crushed and slickensided coal. As this condition is due to a more or less grinding movement in the direction of the bedding, it follows that the whole or a part of the bed has been greatly crushed, and in the forward and backward movements the partings in the bed have become intimately mixed with the coal. This material is so fine that it goes through the screens and produces a very impure slack.

CHEMICAL COMPOSITION.

The real test of a coal is the amount of combustible matter it contains and this, of course, largely depends upon the amount and character of the impurities that are present. The common impurities are moisture, sulphur, and ash. Moisture is very detrimental for it not only takes up space which otherwise would be occupied by combustible matter, but it requires heat to volatilize it and drive it off. Ash is generally an inert impurity, but if it is readily fusible, it may choke the grate bars and become a great detriment to the combustion of the coal. Sulphur is combustible and hence does not materially reduce the heating value, but when not, it corrodes iron very rapidly and this has a bad effect upon grate bars and all metal surfaces with which it comes in contact.

A comparison of results obtained on mine samples and on railroad car samples shows that on the average the ash in the car sample may be from 30 to 50 per cent greater than it is in the mine sample. Thus, coal which shows 6 per cent ash in the mine sample is likely in the car sample to run from 7.8 per cent to 9 per cent, but if it exceeds a 50 per cent increase it indicates gross carelessness in mining or preparing the coal for the market.

The composition of the mine sample may be regarded as the ideal toward which the commercial coal of the mine approaches more and more closely as better methods and more care is exercised in mining and these two will agree whenever the best methods are used and every employe coöperates with the management in excluding impurities from the commercial output of the mine.

COMPARISON OF COALS.

The analyses of the important coals of Wise and Scott counties are averaged and given in the following table to simplify their study and afford a basis for comparison with the important coals of other fields. The first form given for each bed (form A) is the average for the samples "as received" and most nearly represents the condition of the coal as it leaves the mine. The second form (form D) is the average on the "pure coal basis," made theoretically by excluding the moisture and ash from the proximate analysis and recalculating the volatile matter and fixed carbon to total 100 per cent. The second form does not represent the actual condition of the coal at any time and should be used only in a comparative study of the qualities and ranks of the coals.

Averages of analyses of each of the important coals.

	Number of analyses averaged.	Form of analysis.	% moisture.	% volatile matter.	% fixed carbon.	% ash.	% sulphur.	B. t. u.'s.
Lee coals	4	A	2.9	32.2	58.6	6.3	1.09	13670
		D	.....	35.5	64.5	.....	.....	15170
Jawbone	8	A	2.3	30.1	51.3	16.3	1.14	12260
		D	.....	37.0	63.0	.....	.....	15050
Raven	3	A	2.3	32.8	56.4	8.5	1.33	13570
		D	.....	36.8	63.2	.....	.....	15200
Lower Banner	4	A	2.2	32.8	56.4	8.6	.83	13620
		D	.....	36.9	63.1	.....	.....	15320
Upper Banner	11	A	2.8	32.7	57.9	6.6	.56	14160
		D	.....	36.2	63.8	.....	.....	15430
Norton	3	A	3.3	33.1	56.1	7.5	1.42	13630
		D	.....	37.1	62.9	.....	.....	15280
Dorchester (at Norton and Dorchester).	10	A	2.9	34.7	55.5	6.9	1.81	13780
		D	.....	38.4	61.6	.....	.....	15280
Dorchester (at Glamorgan) ..	4	A	2.8	32.4	59.3	5.5	1.13	14130
		D	.....	35.3	64.7	.....	.....	15400
Imboden	15	A	2.4	34.3	57.8	5.5	.75	13960
		D	.....	37.3	62.7	.....	.....	15170
Taggart and Taggart Marker.	6	A	2.1	35.3	60.2	2.4	.57	14660
		D	.....	37.9	62.1	.....	.....	15360
Pardee	11	A	2.8	35.3	55.8	6.1	.99	13770
		D	.....	38.7	61.3	.....	.....	15100
All beds	79	A	2.6	33.2	56.8	7.4	1.06	13730
		D	.....	36.9	63.1	.....	.....	15240
Range		A	.....	5.2	8.9	.....	.....	2400
		D	.....	3.4	3.4	.....	.....	380

The figures given in the table show marked uniformity in the coals of Wise County so far as they are represented by the analyses, especially in the D form, which represents the real coal substance without regard to

ash or other impurities. In the D form the extreme range in the volatile matter is only 3.4 per cent and the same is the range in the figures representing the fixed carbon. The effect of the variable amount of ash is shown in this table by the range of 5.2 per cent in the volatile matter, the 8.9 per cent in the fixed carbon and 2,400 B. t. u.'s in the A form of analysis. The coals of the Lee, Norton, and Wise formations agree essentially in fixed carbon, sulphur, moisture, and B. t. u.'s, but the coals of the Norton and Lee formations run slightly higher in ash and lower in volatile matter than the coals in the Wise formation.

In Fig. 16 the B. t. u.'s or heating values of the important coals in Wise and Scott counties, and the coals of many fields with which the Wise County coals do now, or may possibly in the near future, come into competition, are compared graphically. This method of comparison is more satisfactory for general purposes for in about 99 cases out of 100 the consumer uses coal to produce heat and it is of the uttermost importance to him to know which coal that is available to his house or factory yields the greatest returns. The broken lines in the diagram indicate the heating value of the coal without moisture and ash, or as commonly called, on a pure coal basis. This part of the diagram represents approximately the heating value of the coal substance or the pure coal, as it may be termed. The solid black lines represent the heating value of the coal as it comes from the mine and is necessarily less than that of pure coal, but it more nearly represents the fuel that goes into the furnace than that which represents pure coal.

The high actual heating values of the Wise County coals is clearly shown in Fig. 16. The Taggart coal bed, with an average of 14,660 B. t. u.'s ("A" form) is second only to the famous Pocahontas coal of Tazewell County, Va., which is second to none of the coals of the other districts given. The Blair, Upper Banner, and Dorchester coals are above the 14,000 mark and the Norton, Imboden, and Pardee beds are only slightly below. Of all the outside fields given, including Tazewell County, only the Fayette County, West Virginia, Bell County, Kentucky, and Jefferson County, Alabama, coals have a heating value averaging more than 14,000 B. t. u.'s. It is not intended here to convey the impression that no coals east of the Mississippi River other than those listed exceed 14,000 B. t. u.'s. The coals whose heating values are shown in Fig. 16, are selected from representative eastern and central coal fields of the United States and the averages shown in Fig. 16 are obtained from a large number of analyses in each case.

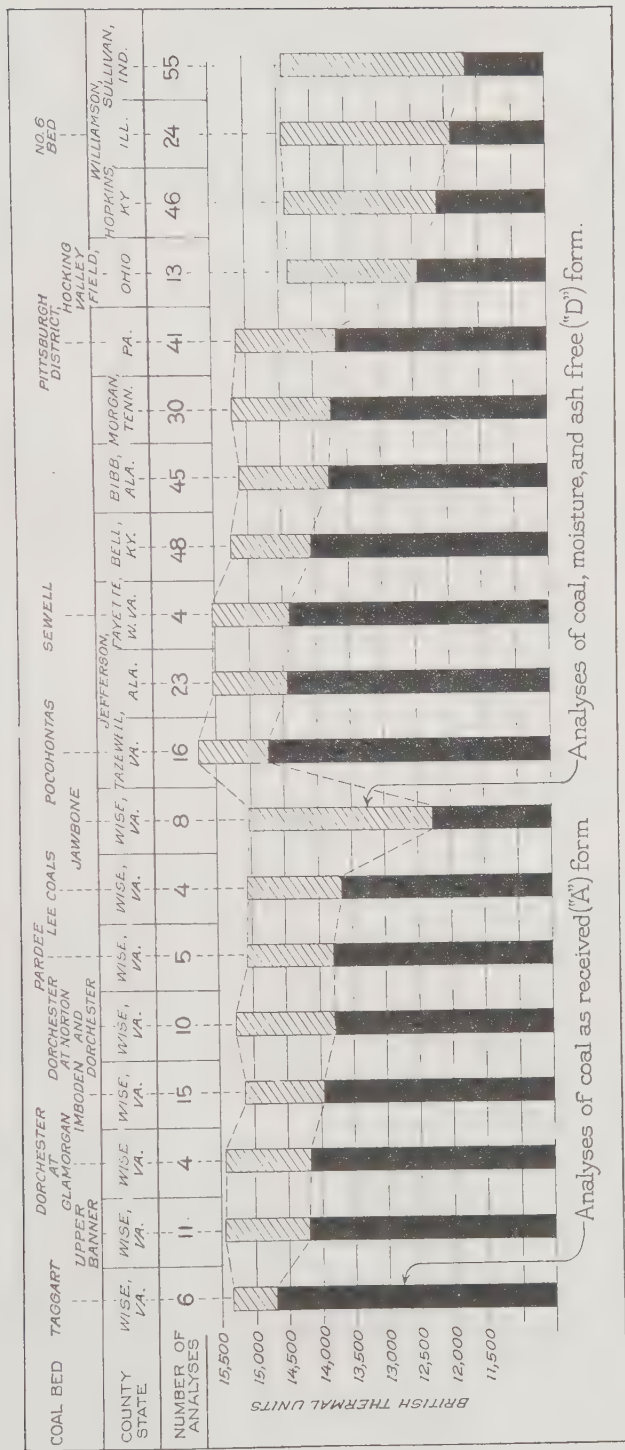


Fig. 16.—Diagram comparing heating value of Wise County coals with coals from other fields.

The Taggart coal averages higher in fixed carbon and lower in ash than any other coal in Wise and Scott counties. The six samples of the Taggart, and its closely associated bed, the Taggart Marker, taken in western Wise County, give the coal an average fixed carbon content of 60.2 per cent, and an ash content of 2.4 per cent. One sample (Analysis No. 33205) shows an ash content of 1.9 per cent, which is remarkably low. The Taggart, therefore, as far as present mining operations have shown, is a high rank (*i. e.*, a high fixed carbon) and low ash coal. This coal is said to make a coke having less than 4 per cent of ash. The Taggart bed is mined at Roda and Dunbar and has been sampled at those two places only in Wise County, hence it should not be taken for granted that the bed everywhere throughout the county maintains this unusually high record of quality. The coal is best adapted to the following purposes, railroad fuel, by-product coking, steam-raising, producing illuminating gas and producer gas, domestic use, bunker coal, and making Beehive coke.

An ultimate analysis of a composite of three samples of Blair coal collected at Esserville shows a heating value of 14,260 B. t. u.'s, and a fixed carbon content of 59.6 per cent. The ash is low, ranging about 5 per cent and the coal is well known as one of the best coking coals in the county.

The Upper Banner coal is one of the high quality coals of Wise County, having in eleven samples taken in eastern Wise County an average heating value of 14,160 B. t. u.'s. It is slightly lower in volatile matter, and fixed carbon and higher in ash than the Taggart, and is the lowest sulphur coal in the county. The coal is best suited for railroad fuel, steam-raising, domestic fuel, and making metallurgical coke.

The Dorchester bed at Glamorgan is second in rank to the Taggart bed with a fixed carbon content of 59.3 per cent. The average heating value of this coal is approximately that of the Upper Banner. The Dorchester bed at Glamorgan, Norton, and Dorchester contains excellent domestic fuel and coking coal.

The Imboden coal has a heating value only slightly below that of the Dorchester and Upper Banner coals but is equal in rank and ash content. A sample of Imboden coal (Analysis No. 75965) collected in a mine at Arno, yielded on analysis an ash content of only 1.2 per cent, which is extraordinarily low and is the lowest ash sample that was taken from any bed in Wise or Scott counties. The average ash content as determined by fifteen samples is 5.5 per cent. The Imboden bed is the largest producing

bed in the county and the coal is used principally for bunker coal and for making coke. The coal is also valuable as a railroad fuel, by-product coal and steam-raising coal.

The average of eleven analyses of Pardee coal shows that coal to be of high heating value, of low-ash content, and slightly lower in rank than the average of Wise County coals. A study of the individual samples and the sections of the bed included in the samples show that the quality of the coal in the bed is not uniform throughout its entire 10 feet of thickness but that a top layer from 1 to 3 feet thick is relatively high in ash and sulphur. This top layer, in mining, is usually left as a roof but in old parts of the Pardee mines it is in large part removed. Where the entire bed is included in the sample, the analysis shows an ash content up to 10 per cent, but where only the section normally mined is sampled the ash content is about 4 per cent to 6 per cent. The coal is hard, making excellent lump coal, and is largely used as domestic fuel.

The effect of high-ash on the heating value of a coal is graphically shown in Fig. 16 for the Jawbone coal. The ash content of this coal determined from eight samples is 16.3 per cent and the heating value is 12,260 B. t. u.'s. The Jawbone is the highest ash and lowest rank coal now mined in the county, but the very large production of coal from this bed is sufficient evidence of the minable character of the coal, showing that the term high-ash, as here applied, is relative only to the other coals of Wise County.

The Raven, Lower Banner, and Norton beds are closely akin in character and quality, running about 33 per cent volatile matter, 56 per cent fixed carbon and 13,600 B. t. u.'s. The Norton bed is lower in ash and higher in sulphur than the other two beds. All three, however, are excellent coals and are extensively mined.

The coals of Wise County compare most advantageously in rank, ash content, and calorific value, with the bituminous coals of other States (see fig. 16). The local coals average higher in rank and heating values than the coals of Pike and Letcher counties, Kentucky, and considerably higher than those of Hopkins County, in the western Kentucky field. The Wise County coals are equal to and in some cases exceed the highest rank of the Kanawha coals of southern West Virginia, namely those along the easternmost border of the Kanawha field.

The Pocahontas and New River coals are distinctly above the coals of this part of the Virginia region in rank, being 5 to 15 per cent higher in fixed carbon, and are in general their equal in lowness of ash and sulphur

content, while, as is to be expected, their more advanced rank gives them somewhat greater B. t. u. values. Also, the New River and Pocahontas coals are coked with less loss of volatile matter. On the other hand, for household use and for export to markets intolerant of great quantities of slack or fine coal, most of the Virginia coals, which have not been so crushed and made friable by the dynamic forces that gave the Pocahontas and New River coals their higher rank, have a distinct advantage on account of the larger proportion of lump coal which may even permit grading by sizes with smaller waste in dust or slack. The Virginia coal especially commends itself as a reasonably high rank, high heat value, low ash, and low sulphur lump coal for export, as well as for domestic use.

Compared with the Tennessee coals these coals, on account of the higher rank resulting from the greater elimination of volatile matter, have a greater calorific value and are lower in ash and sulphur content. In the areas of extraordinarily low ash coals, like Campbell and Claiborne counties in Tennessee, the rank of the coals is so low as to give them a calorific value perceptibly less than that of the Virginia coals, in which, moreover, the sulphur is nearly everywhere smaller in amount. The heating value of the coals of Morgan County, Tennessee, is about that of the Wise County coals taken as a whole (see fig. 16).

The coals of Alabama vary greatly in quality. In some localities the fuel is clearly of higher rank and heating power than that of the Virginia area, though nearly everywhere higher sulphur is found in the former than in the latter. In general, the Alabama coals are higher in ash and are inferior in rank and calorific value to the coals of Wise County. The heating value of coals from Jefferson and Bibb counties, Alabama, is graphically shown in Fig. 16.

As compared with the coals of the other Mississippi Valley states, including Illinois, Indiana, and western Kentucky (see fig. 16), the Virginia coals are distinctly superior, being of considerably higher rank, generally lower in ash, almost everywhere lower in sulphur, and much higher in calorific value. The differences in the calorific value, which often exceeds 2,000 B. t. u.'s in favor of the Virginia coal, will possibly be found in some foreign market that is partial to lump coal, to be pitted against the larger percentages of stronger lump in the coals of the upper Mississippi Valley.

Even the best coals of Ohio are so much lower in fixed carbon, i. e., in rank, as hardly to equal the Virginia coals in heat value, and the Ohio coals are higher in sulphur and in ash (see fig. 16).

The coals of the upper Potomac and Georges Creek basins in western Maryland are clearly much higher in rank, but their heat value is reduced by their higher ash content. The coal in the southern part of the Potomac basin and neighboring region of West Virginia are locally clearly superior in purity and heat value to the Wise County coals. These high-rank coals yield a larger proportion of fine coal or slack in the run-of-mine product. The average analysis of 41 samples from the Pittsburgh district, Pennsylvania, show the coals of that district to equal in calorific value the average of the Wise County coals (see fig. 16).

The Virginia coals concerned in this study seem to compare most closely, in rank, heat value, ash, and moisture content, in the northern Appalachian region, with the low ash coals of the Fairmont district in northern West Virginia and in the Uniontown-Connellsville zone of Pennsylvania. Their low ash, low moisture, and abnormally low sulphur content give the Virginia coals an advantage over those in northwestern West Virginia and in western Pennsylvania, toward the western borders of which the lower fixed carbon is attended in general by lower calorific values.

TESTS.

GENERAL STATEMENT.

Samples of coal from two localities in eastern Wise County were subjected to a series of tests in fuel-testing plants of the United States Geological Survey to determine their value for commercial purposes. A run-of-mine sample from the Jawbone coal bed in the Virginia City No. 1 mine, of the Virginia Iron, Coal & Coke Co., at Virginia City, was used in making steaming and producer-gas tests in the plant at Norfolk, Va. It had been exposed to weathering for 36 days before use at the testing plant. A car sample of lump coal, over a $3\frac{1}{2}$ inch bar screen, from the Upper Banner coal bed in the Coeburn mine of the Virginia Iron, Coal & Coke Co., at Toms Creek, was tested in the St. Louis plant.

The value of these tests is now relatively small in view of the fact that coal testing apparatus and methods have changed greatly in the past 15 years and standards for comparison are difficult to obtain. Furthermore, the two coals tested, the Jawbone and Upper Banner, have been mined continuously for about 30 years and the tests above referred to add little to the well-known properties of the coals in question. Thus, for example, the Upper Banner coal has been coked to great advantage and on a large scale continuously since mining began, and it needs no special tests to prove

this quality. For these reasons only the most fundamental results of these tests will be quoted in this report, and for the full description of the tests, the apparatus used, and the results of obtained, the reader is referred to bulletins of the United States Bureau of Mines and the United States Geological Survey¹ and to bulletins of the Virginia Geological Survey.²

Four steaming tests were made on Wise County coals, two on Jawbone coal and two on Upper Banner coal. The essential features of the steaming tests are given in the following summary:

SUMMARY OF STEAMING TESTS.

	Test 601. Jawbone.	Test 602. Jawbone.	Test 280. Upper Banner.	Test 283. Upper Banner.
Water apparently evaporated per pound of coal as fired .....pounds..	7.70	7.07	8.14	8.18
Water evaporated from and at 212° F.:				
Per pound of coal as fired .....pounds..	8.94	8.32	9.74	9.79
Per pound of dry coal .....pounds..	9.06	8.46	9.91	10.12
Per pound of combustible .....pounds..	10.97	10.36	10.66	10.84

Producer-gas tests were made on one sample of Upper Banner coal and on one sample of Jawbone coal. The coal used in producer (pounds per electrical horsepower per hour) are given below, first, as available for outside purposes, and, secondly, as developed at switch board. The tests are recorded as follows:

¹ Burrows, J. S., Mine sampling and chemical analysis of coals: U. S. Geol. Survey Bull. 362, 1907.

Breckenridge, L. P., Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905: U. S. Geol. Survey Bull. 290, 1906.

Breckenridge, L. P., Kreisinger, Henry, and Tay, W. T., Steaming Tests of coals and related investigations: Bureau of Mines Bull. 23, 1912.

Fernald, R. H., and Smith, C. D., Résumé of producer-gas investigations: Bureau of Mines Bull. 13, 1911.

Belden, A. W., Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905: U. S. Geol. Survey Bull. 290, 1906.

Belden, A. W., Washing and coking tests of coals and cupola tests of coke: U. S. Geol. Survey Bull. 336, 1908.

² Giles, A. W., The Geology and Coal Resources of Dickenson County, Virginia: Va. Geol. Survey Bull. XXI, pp. 206-212, 1921.

Wentworth, C. K., The Geology and Coal Resources of Russell County, Virginia: Va. Geol. Survey Bull. XXII, pp. 124-129, 1922.

SUMMARY OF PRODUCER-GAS TESTS.

	Test 163. Jawbone.			Test 75. Upper Banner.		
	Coal as fired.	Dry coal.	Com- busti- ble.	Coal as fired.	Dry coal.	Com- busti- ble.
Per electrical horse-power:						
Available for outside purposes	1.52	1.50	1.26	1.29	1.27	1.21
Developed at switch-board	1.48	1.46	1.23	1.21	1.19	1.13

Coking tests were made on two sample lots of the Upper Banner coal from Toms Creek. The coke obtained was of excellent quality and compared most favorably with 12-hour Connellsville coke.

ANALYSIS OF COAL AS USED AND RESULTING COKE.

	Connellsville.	Test 61. Upper Banner.		Test 88. Upper Banner.	
	Coke.	Coal.	Coke.	Coal.	
Moisture	.18	2.87	0.29	2.49	0.16
Volatile matter	.32	31.58	1.21	31.90	1.26
Fixed carbon	88.75	61.43	92.60	61.16	91.85
Ash	10.75	4.12	5.90	4.45	6.73
Sulphur in coke	.87	.56	.61	.57	.55
Sulphur in ash	.033		.085		.070
Phosphorus	.018		.001		.006
Specific gravity	1.92		1.93		1.87

The coal in test 61 was finely crushed and in test 88 the coal shipped had first been passed over a 3½-inch bar screen. Test 61 was of 45 hours' duration and test 88 was of 50 hours' duration. The coke produced from both tests was light gray and silvery color; had much deposited carbon, metallic ring, small cell structure, good breakage, and was heavy.

FUSIBILITY OF ASH FROM COALS OF WISE AND SCOTT COUNTIES.

The formation of clinker resulting from the melting of the ash of the burning coal has long been a troublesome problem, and it has led the United States Bureau of Mines to make a general survey of the "fusing" or "softening" temperatures of ash from various coals of the United States.

The Bureau has published two reports on the fusibility of coal ash, Bulletin 129¹ and Bulletin 209,² to which the reader is referred for a detailed description of the methods and apparatus used in determining the fusion points of coal ash. In the latter bulletin are given the results of several hundred fusion tests made with ash from coals collected in many of the coal fields of the United States and Alaska. Forty-two tests are given on the ash from coals of Wise and Scott counties and appear in the following table. In order to present a clearer understanding of the table the following discussion on the relationship of ash to fusibility and fusibility to clinker formation is extracted from Bulletin 209.²

"SOURCE AND COMPOSITION OF COAL ASH.

"Coal ash is the incombustible residue remaining after the complete combustion of coal; it is derived from the inorganic mineral constituents of the coal. The ash-forming constituents are (1) inherent or intrinsic impurities that are present in an intimate mixture with the coal substance, and are derived either from the original material or from external sources such as sedimentation and precipitation while the coal-forming plant remains accumulated; (2) impurities, formed either during the laying down of the coal bed or subsequently, that occur in the form of partings, veins, and nodules of clay, shale, "slate," pyrite, and calcite; and (3) impurities that become intimately mixed with the coal in the process of mining, such as fragments of roof and floor.

"Coal ash is composed largely of compounds of silica, alumina, lime, and iron, with smaller quantities of magnesia, titanium, and alkali compounds. The chemical composition varies so widely that no typical composition can be given. In general, the analyses of most coal ash will probably come between the following limits:

"TYPICAL LIMITS OF ASH ANALYSES.

Constituent.	Per cent.	Constituent.	Per cent.
SiO ₂	40-60	CaO	1-15
Al ₂ O ₃	20-35	MgO	5-4
Fe ₂ O ₃	5-25	Na ₂ O+K ₂ O	1-4

"This list of constituents shows that coal ash contains relatively large proportions of SiO₂ and Al₂O₃, and smaller proportions of the other oxides.

¹ Fieldner, A. C., Hall, A. E., and Field, A. L., The fusibility of coal ash and the determination of the softening temperature: Bureau of Mines, 1918, 146 pp.

² Selvig, W. A., and Fieldner, A. C., The fusibility of ash from coals of the United States, Bull. 209, Bureau of Mines, 1922, 119 pp.

"RELATION BETWEEN CHEMICAL COMPOSITION AND FUSIBILITY OF COAL ASH.

"The fusibility of coal ash depends on several factors, such as the ratio of the silica to the bases present, the particular bases, and the percentage of alumina present. Mixtures extremely high in silica or extremely high in bases are not readily fusible. Ash that is low in iron is usually so highly siliceous that it is not readily fusible. Ash from coals high in pyrite is necessarily high in iron, and the ratio between the bases and silica is often such that easily fusible compounds may be formed. As a rule, coals containing considerable sulphur in the form of pyrite are apt to give trouble from clinker formation. Under conditions of the fuel bed the iron of the pyrite is apt to be converted to ferrous oxide, which with the silica present forms ferrous silicates that fuse at comparatively low temperatures. The chemical analyses of a series of five coal ashes ranging from very fusible (softening at 2,060° F.) to highly refractory (softening above 2,900° F.) is as follows:

"CHEMICAL ANALYSES OF FIVE COAL ASHES COVERING A WIDE RANGE OF FUSIBILITY.

Sample No. ^a	Softening temperature, ° F.	Analyses of ash, percentage of—								
		SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	TiO ₂	CaO	MgO	Na ₂ O	K ₂ O	SO ₃
1	2,060	30.7	19.6	18.9	1.1	11.3	3.7	1.9	.5	12.2
2	2,320	46.2	22.9	7.7	1.0	10.1	1.6	.7	.8	8.9
3	2,500	49.7	26.8	11.4	1.2	4.2	.8	1.6	1.3	2.5
4	2,730	51.0	30.9	10.7	1.9	2.1	.9	1.0	.4	.6
5	+2,900	58.5	30.6	4.2	1.8	2.0	.4	.7	.9	.9

^a Sample 1, subbituminous coal, Montana; 2, bituminous coal, No. 6 bed, Illinois; 3, bituminous coal, Pittsburgh bed, Pennsylvania; 4, semibituminous coal, Pocahontas No. 3 bed, West Virginia; 5, bituminous coal, Dean bed, Kentucky.

"RELATION OF FUSIBILITY TESTS TO CLINKER FORMATION.

"It is well to bear in mind that the conditions of fusibility tests in the laboratory may not be directly comparable to the conditions in the fuel bed of a furnace. In a laboratory test the ash-forming constituents are intimately mixed, whereas there is usually no such uniform distribution of the ash-forming constituents in coal fire.

"Some coal ash is so infusible that little trouble is experienced from the formation of clinker. Ash that is slightly more fusible will often form a porous, spongy clinker which does not seriously obstruct the flow of air through the fuel bed and is easily removed. Coal ash with a low fusing temperature, say 2,100° F., not only melts in the

average fire box, but is heated several hundred degrees above its melting temperature, becoming quite fluid and spreading out in a thin sheet over the grate, thereby obstructing the flow of air and localizing the heat in the fuel bed.

"The method adopted for making fusibility tests was the result of considerable experimental work,¹ by the Bureau of Mines on the nature of the fusion of coal ash and the influence of various oxidizing, reducing, and neutral atmospheres on the softening temperature of ash molded in the form of Seger cones. The method takes into consideration the various factors that influence the result obtained, with special reference to the atmosphere surrounding the ash during the test. The atmosphere in which the ash is heated is controlled by burning an excess of gas; a reducing atmosphere is thus obtained by which the iron in the ash is reduced mainly to the ferrous state, giving the lowest temperature at which clinkering may result.

"Analyses of clinkers from boiler furnaces indicate that fuel-bed conditions favored the formation of clinkers in which the iron was chiefly in the ferrous state; consequently the values obtained in the laboratory tests are, in this respect, comparable to such conditions, and the tests give the lowest temperatures at which the intimately mixed ash will soften with the formation of clinker."

The coals occurring in Wise and Scott counties are all of bituminous rank. The samples of coal from which the following ash fusibility determinations were made were collected according to a standard method by representatives of the United States Geological Survey. In all cases but one (the outcrop sample taken at Dooley) the samples were collected in mines or prospects. In the following table are given the names of the locality, the mine, the coal bed, and the laboratory number, the number of samples from each mine, the lowest, highest, and average softening temperature in degrees Fahrenheit and the percentage of ash and sulphur in the dry coal are tabulated for each mine. Samples of ash remaining unfused at 3,010° F., which was the highest temperature attained in the tests, are marked +3010 and used as such in figuring the average values for the mine.

The authors of Bulletin 209 in discussing the fusibility values of the coals of the United States first define the classes of fusibility and then give brief comparisons of the tests of the ash from eastern, interior, and western

¹ Fieldner, A. C., Hall, A. E., and Field, A. L., The fusibility of coal ash and the determination of the softening temperature: Bull. 129, Bureau of Mines, 1918, 146 pp.

Softening temperatures of coal ash from coals of Wise and Scott counties, Va.

Locality.	Mine.	Coal bed.	Analysis No.	Number of samples from mine.	Softening temperature ° F.			Average analysis of dry coal, percentage of—		
					Lowest.	Highest.	Average.	Ash.	Sulphur.	
WISE COUNTY.										
Arno	Rock Heading No. 2	Imboden	75964 66	9	2,690	2,700	2,670	4.19	.65	
Banner	Lower Banner No. 1	Lower Banner	32509-10	2	2,410	2,420	2,420	7.65	.72	
Do.	Do.	Upper Banner	32512	1			2,270	4.66	.91	
Dorchester	Haskell No. 3	Dorchester	75440-41	2	2,290	2,240	2,220	5.03	1.45	
Dunbar	Do.	Taggart Marker	32962	1			2,330	2.78	.77	
Esserville	Do.	Taggart	32963	1			2,370	3.06	.63	
Flat Gap	Essex No. 4	Blair	75359-61	3	2,500	2,620	2,570	5.91	1.00	
Glamorgan	Reuben Bolling	Imboden	15174	1			2,720	8.74	1.32	
Do.	Glamorgan No. 3	Dorchester	15106-01	2	2,130	2,190	2,160	5.86	1.22	
Imboden	Stone Gap No. 3	Do.	32322-43	2	2,220	2,370	2,300	5.40	1.17	
Imman	Imboden No. 2	Imboden	75973-74	2	2,450	2,680	2,570	5.11	.84	
Josephine	Virginia Iron No. 2	Do.	75979-70	2	2,390	2,380	2,390	7.13	.80	
Norton	Intermont No. 6	Dorchester	32067-68	2	2,540	2,640	2,590	10.25	.80	
Do.	Norton No. 2	Do.	75353-65	3	2,140	2,190	2,160	6.84	2.29	
Do.	Norton No. 4	Blair	10390	1			2,600	3.89	.93	
Osaka	Osaka	Imboden	33182-84	3	2,950	2,980	2,970	5.49	.72	
Pardee	Pardee No. 1	Pardee (Parsons)	33140-41	2	2,890	2,950	2,920	9.52	1.23	
Do.	Do.	Do.	15069, 22279	2	2,420	2,500	2,460	8.04	1.59	
Roaring Fork	Roaring Fork	Kelly	33143-44	2	2,370	2,890	2,630	6.53	.94	
Roda	Stonega No. 3	Taggart	33203-06	4	2,190	2,370	2,320	2.28	.53	
St. Paul	Twin City No. 1	Imboden	32276	1			2,240	12.69	2.22	
Do.	Twin City No. 2	Jawbone	32277	1			2,910	13.22	.73	
Do.	Twin City No. 3	Do.	33188	1			2,240	19.86	1.03	
Stonega	Stonega No. 2	Imboden	33186-87	1			2,980	4.96	.77	
Do.	Stonega No. 3	Do.	33186-88	1			2,920	8.03	.77	
Sutherland	Clark No. 2	Dorchester	75436-38	3	2,870	2,180	2,130	6.64	2.37	
Tacoma	Beaver	Lower Banner	75446-47	2	2,720	2,910	2,820	10.50	.96	
Do.	Bolling	Raven	75443-44	2	2,560	2,910	2,580	6.70	.94	
Tom's Creek	Caney	Upper Banner	32407-08	2	2,370	2,640	2,510	6.31	.57	
Do.	Cranechest No. 1	Do.	18226-28	3	2,510	2,660	2,580	5.23	.55	
Do.	Lee No. 6	Do.	32410-11	2	2,370	2,580	2,480	5.25	.51	
Do.	Sexton No. 2	Do.	32413	1			2,380	14.84	.62	
Do.	Thelma No. 1	Do.	32404-05	2	2,270	2,430	2,350	8.90	.55	
Tom's Creek	Swansea	Upper Banner	10385	2			2,520	5.65	.53	
Virginia City	Virginia Iron	Jawbone	32503-06	4	2,220	2,470	2,320	17.42	1.28	
Wise	Dean Brothers	Rocky Fork	75746	1			2,820	6.45	.78	
Do.	Gladville No. 3	Norton	75367-69	3	2,270	2,460	2,360	7.76	1.47	
SCOTT COUNTY.										
Adamar	Hagan	Burtons Ford	10359	1			2,530	29.61	1.01	
Dunganon	J. S. T.	Do.	75743-44	2	2,740	2,780	2,760	7.12	.91	
Ka	Miner prospect	Miner	10358	1			2,120	5.89	1.69	
Do.	Hagan prospect	Duncan	10361	1			2,160	6.65	.88	

coals. Only that portion of this discussion which is of value in comparing the fusibility tests of coals of Wise and Scott counties will be quoted here.¹

"CLASSES OF FUSIBILITY.

"In general, the softening temperature of coal ash from the coals of the United States ranges from 1,900° to 3,100° F. For convenience in discussion, the order of fusibility of ash may be expressed by subdividing this range of softening temperature into three groups, as follows:

"Classes 1, refractory, softening above 2,600° F.

"Class 2, ashes of medium fusibility, softening between 2,200° and 2,600° F.

"Class 3, easily fusible ashes, softening below 2,200° F."

A study of the 73 tests of the coals of Wise County shows that the average fusibility of the ash is very close to 2,500° F. The average fusibility of the Upper Banner coal ash is a little less than 2,500° F., and the ash belongs to the class of medium fusibility. The average fusibility of the Imboden ash exceeds 2,650° F., and it belongs to the "refractory" class. The Dorchester coal ash is characterized by low fusibility. The silica content of the ash varies in different beds and for different parts of the same bed, however; hence the desirability and importance of having as many determinations as possible for each bed to arrive at a fair average of ash fusibility. The Upper Banner, Dorchester and Imboden coal beds are the only ones in this field that have been sampled at five or more mines and for which it might be said a fair average could be ascertained.

¹ Op. cit., pp. 10-11.

V I T A

James Brian Eby was born near Littlestown, Adams County, Pennsylvania, December 18, 1896. His early education was received in the public schools of Baltimore. He entered the Baltimore City College (high school) in September, 1911, graduating in June, 1915. In the fall of 1915 he entered Johns Hopkins University where, in June, 1918, he received the degree of Bachelor of Arts, one month after having enlisted in the United States Army. After serving seven months in the Army he was honorably discharged and commissioned Second Lieutenant of Infantry in the Reserve Corps. He entered the graduate department of geology at Johns Hopkins University January 6, 1919. On March 12, 1919, he passed the Civil Service examination for Geologic Aid on the United States Geological Survey, and was appointed on the Survey March 11, 1920. Following his appointment he spent two weeks in office work in Washington, and was then furloughed to complete his year at the University, where he had been attending the graduate classes and laboratories for the academic year, 1919-1920. During the previous summer (1919) he held the position of reporter on the *Baltimore American*, covering special assignments.

On June 22, 1920 he began field work in Wise County, Virginia, as assistant to Chester K. Wentworth, Associate Geologist. Mr. Wentworth returned to Washington September 17, 1920, Mr. Eby remaining in the field until October 22nd of that year. During the academic year 1920-1921, his time was divided between work at the University and on the Survey, where he was engaged in the preparation of a report on the geology of Wise County.

He took the examination for Assistant Geologist February 24, 1920, which he passed, and was promoted to that grade July 1, 1920. He returned to Wise County, Va., April 11th, where he remained until June 3, 1921, when he had completed the field work necessary for the report. From July 18th to July 29th he traveled through southwest Virginia collecting data for the Mineral Resources Branch of the United States Geological Survey. On August 2nd he left for central Montana, where he acted as instrument-man for Doctor Frank Reeves, of the Geological Survey, who was carrying on oil and gas investigations in that State. He returned to Johns Hopkins September 17, 1921, and received his doctorate degree in June, 1922.

Mr. Eby has pursued work in the graduate department of Johns Hopkins in physical chemistry under Professor Patrick, and in geology under Professors Mathews, Reid, Berry, Swartz, and Singewald. His special field of work has been stratigraphy and economic geology.

